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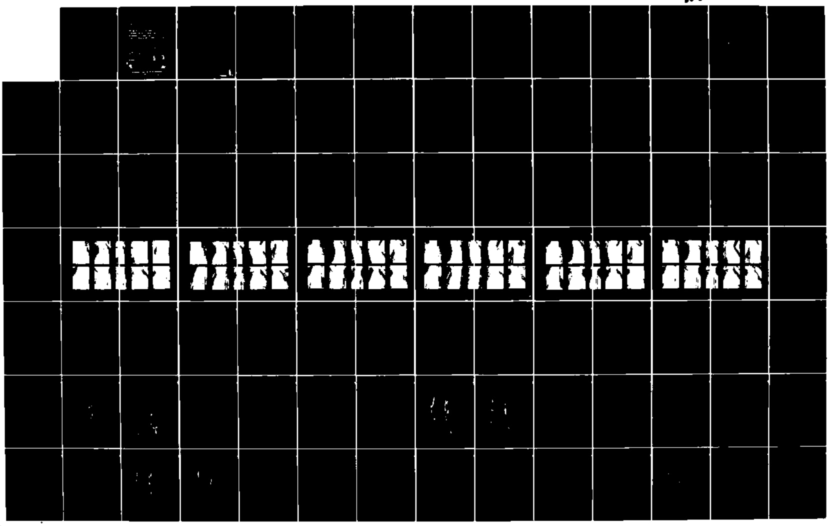

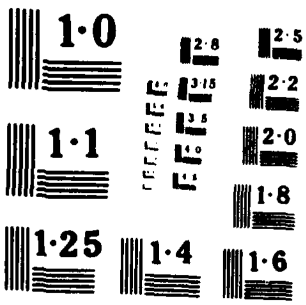
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HYDRAULIC MODEL
INVESTIGATION

TECHNICAL REPORT NO. 124-1

7

Navigation Channel Improvement, Columbia River, Oregon and Washington - Oak Point to Longview Reach, River Miles 53 to 65

SPONSORED BY
U. S. ARMY CORPS OF ENGINEERS
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A distorted scale (1:100 V, 1:300 H) movable-bed hydraulic model was used to evaluate 5 separate channel improvement designs in the Columbia River navigation channel between RM's 53 to 65. Descriptions of the tests and data relative to resulting channel scour and fill conditions are presented in the report.

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PREFACE

Model investigation of channel improvements in the Columbia River was requested by the U.S. Army Engineer District, Portland (NPP), in letters to the U.S. Army Engineer Division, North Pacific (NPD), dated 19 February and 4 November 1963. Authorizations to perform the overall study were granted on 4 April 1963 and 4 March 1964 by the Office, Chief of Engineers (OCE). The authorizations designated that the Columbia River from River Mile (RM) 52 to 109 be studied using five separate movable-bed models. The models were to remain available for operation for an extended period as long as results would be beneficial for new construction on the river and for operation and maintenance activities. The model covering the reach from RM 53 to 65 is the subject of this report.

Tests were conducted on the reach from RM 53 to 65 during the period March 1966 to September 1970. The studies were conducted in the North Pacific Division Hydraulic Laboratory (NPDHL). A cooperative effort was developed with U.S. Army Engineer Waterways Experiment Station (WES) to achieve satisfactory verification of model performance. The model studies were under the direct supervision of Messrs. H. P. Theus, Director, and A. J. Chanda, Chief of the Hydraulics Branch. The engineer in immediate charge was Mr. B. B. Bradfield. Much of the initial report material was also written and organized by Mr. Bradfield. This report was prepared by Northwest Hydraulic Consultants

Incorporated, and the U.S. Army Engineer District, Seattle, and makes use of Mr. Bradfield's earlier work.

During the course of this investigation, personnel of OCE, NPD, and NPP visited the laboratory to observe model operation and discuss test results. Close liaison was maintained with NPP personnel, and as tests were completed the results were furnished to those concerned. In addition, the model was demonstrated to members of port authorities and chambers of commerce, congressmen, public officials, fishing and navigation interests, and various interested parties. Public demonstrations of the model were held on 25 October 1966, 16 November 1966, and 1 May 1968. The model was demonstrated and current results of the study were discussed before the Committee on Channel Stabilization during the sixteenth meeting, 1-3 August 1967, and the twenty-second meeting, 21-23 July 1970.

CONTENTS

CONVERSION FACTORS, BRITISH TO METRIC UNITS OF MEASUREMENTS

British units of measurement used in this report can be converted to metric units as follows:

Multiply	By	To Obtain
inches	2.54	centimeters
feet	0.3048	meters
miles (statute)	1.6093	kilometers
feet per second	0.3048	meters per second
cubic feet per second	0.02832	cubic meters per second
cubic feet	0.02832	cubic meters
cubic yards	0.7646	cubic meters

NAVIGATION CHANNEL IMPROVEMENT

COLUMBIA RIVER, OREGON AND WASHINGTON

OAK POINT TO LONGVIEW REACH

RIVER MILES 53 TO 65

Hydraulic Model Investigation

PART I: INTRODUCTION

Description of Project

1. The Columbia River, the largest river on the Pacific Coast, has drawn the attention of navigation interests since the discovery of its estuary in 1792. Beginning with the establishment of Astoria, Oregon, in 1811, the growth of numerous cities along the lower 110 miles* of its shores precipitated the need for a dependable channel for waterborne commerce. Originally, several bars within this lower reach of the Columbia had depths of only 12 to 15 ft at low water. The first project to establish a 20-ft depth was authorized by the Federal Government in 1878, and the first control works were installed the same year. With increasing demands for ocean commerce, the channel depth was subsequently increased to 25 ft by authorization of Congress in 1892. In 1912 the channel was further enlarged to a depth of 30 ft and width of 300 ft. Work was begun in 1930 to improve the channel to a depth of 35 ft and a width of 500 ft. Due to the increasing size of ships, the promise of greater use of the

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* A table of factors for converting British units of measurement to metric units is presented on page iv.

river, and the benefit to industrial expension, Congress approved the River and Harbor Act of 1962 which provides for a 40-ft navigation channel.

2. The dredging project authorized in 1962 provides for a channel 40 ft deep and 600 ft wide from near the river's mouth (RM 3)* to the mouth of the Willamette River (RM 101.5); then a channel 40 ft deep and 600 ft wide to the Burlington Northern railroad bridge at Vancouver, Washington (RM 105.5); and then a channel 35 ft deep and 500 ft wide to the Interstate 5 bridge which is the easterly end of the dredging project (RM 106.5). One turning basin 6,000 ft long by 1,200 ft wide and 40 ft deep is provided at Longview, Washington, and two turning basins are provided at Vancouver, Washington. The lower basin is 6,000 ft long by 1,200 ft wide and 40 ft deep, while the upper basin is 2,000 ft long by 800 ft wide and 35 ft deep. The project also includes 30- and 24-ft-deep auxiliary channels from the Columbia River channel to Mount St. Helens (RM 87) and Rainier, Oregon, (RM 68), respectively. Side channels are located at Cathlamet and Longview.

Purpose of Study

3. The general purpose of this study was to provide information relative to the effect of the proposed enlargement of the existing 35- by 500-ft navigation channel to 40 by 600 ft along a

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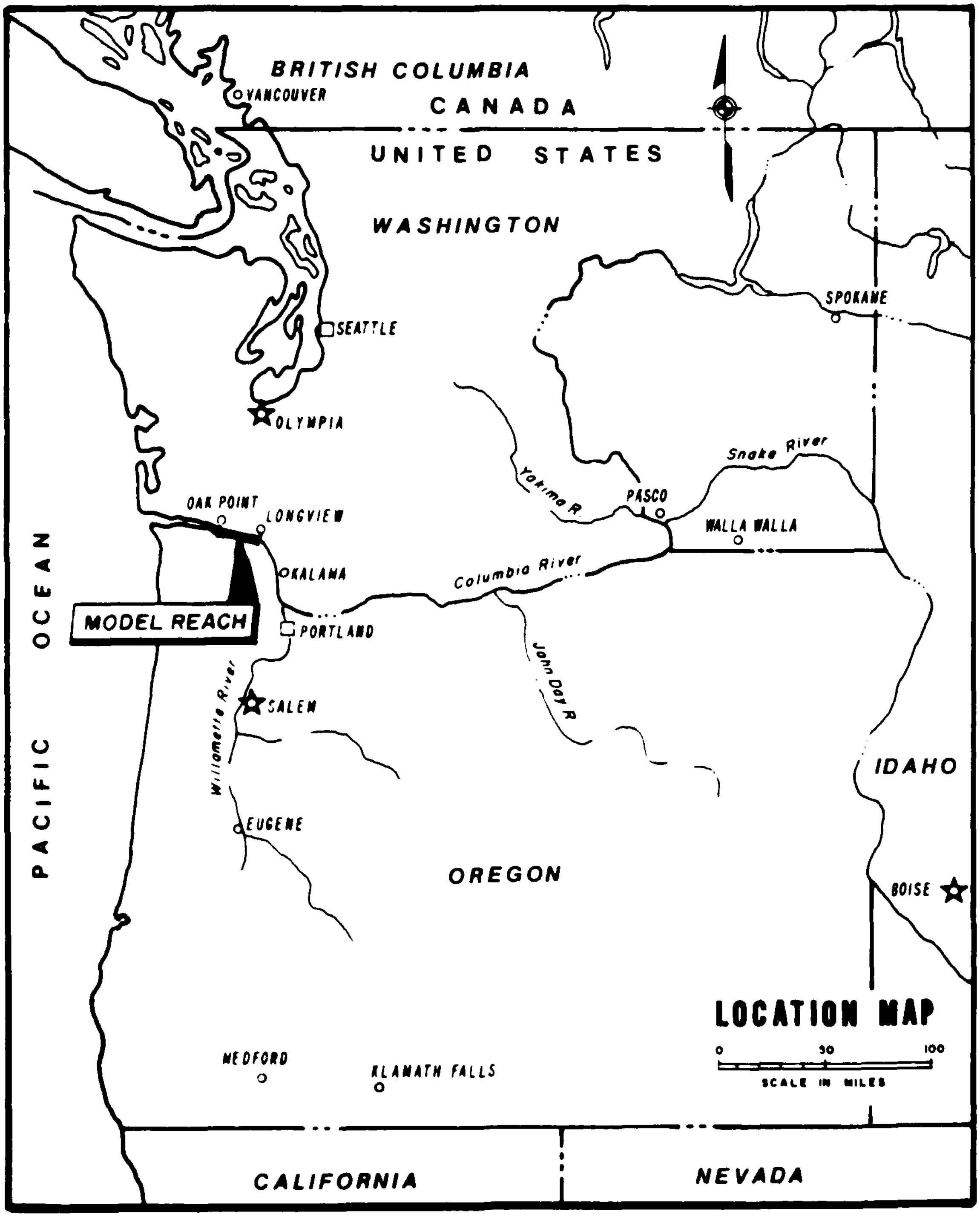
* RM 3 and all mileage cited henceforth are in RM measured from a point inline with the out end of the jetties at the mouth of the Columbia.

12-mile reach--RM 53 to 65. The effect and efficiency of proposed plans for control structures, navigation channel alignment, and location of dredge disposal areas were to be studied in order to determine the optimum plan for reducing initial and maintenance dredging.

The Prototype

4. The Columbia River has its origin in Lake Columbia, British Columbia, Canada, and follows a 1,210-mile indirect course in a generally southwesterly direction to the sea. The quarter-million square-mile drainage basin of the river encompasses the rugged, mountainous region of the Pacific Northwest--covering large portions of the States of Washington, Oregon, and Idaho--and extends into British Columbia. The drainage basin also includes small portions of northern Nevada and Utah and the western parts of Wyoming and Montana. The total fall of the river from the source to the sea is about 2,640 ft. In the final 110 miles from Vancouver, Washington, to the ocean (which includes the reach concerned with herein), the gradient sharply decreases with a fall of only about 5.5 ft in this distance at low water datum. Figure 1 shows the general site location and the river reach discussed in this study.

5. Within the reach of the Columbia involving the 40-ft channel project, there are 26 bars or problem areas which require annual maintenance dredging. Three of these bars are investigated in this study as follows: Walker Island-La Du (RM 59.6 to 63.2); Stella Fisher (RM 55.7 to 59.6); and Gull Island (RM 53.0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CANADA
VANCOUVER
UNITED STATES
WASHINGTON
SEATTLE
OLYMPIA
SPOKANE
Snake River
Yakima R
PASCO
WALLA WALLA
OAK POINT
LONGVIEW
KALAMA
Columbia River
MODEL REACH
PORTLAND
PACIFIC OCEAN
Willamette River
SALEM
John Day R
IDAHO
EUGENE
OREGON
BOISE
LOCATION MAP
0
50
100
SCALE IN MILES
MEDFORD
KLAMATH FALLS
CALIFORNIA
NEVADA

Figure 1

to 55.7). At the time of project authorization, the reach from RM 53 to 65 contained 18 pile dikes (located as shown on plate 1) totaling approximately 15,600 ft in length. These permeable groins helped to control the channel regime by stabilizing bank lines and dredge disposal areas and by maintaining the desired cross sectional dimensions of the river channel. A 28- to 30-ft-deep and 250- to 300-ft-wide auxillary navigation channel, parallel to the main channel, is maintained from RM 63.25 to 65.0. Three secondary river channels--Walker Island slough, Fisher channel, and Bradbury slough--provide additional avenues for shallow-draft commerce.

6. The annual hydrograph for the lower Columbia River has two freshets. The major floods occur during the months of May, June, and July as a result of snowmelt. The secondary floods occur during the months of December and January and are due to winter rains in the Willamette valley. Maximum freshwater discharge has been estimated at 1,240,000 cfs, and the average maximum mean daily discharge is approximately 600,000 cfs for the reach of the Columbia discussed in this report.

7. The tidal effect on the lower Columbia River extends upstream as far as 141 miles during periods of low river discharge, and reversals of flow extend as far as 90 miles upstream. The diurnal tidal range (from mean higher high water to mean lower low water) at the mouth of the river is 8.3 ft; at RM 52, 5.5 ft; and at RM 78, 3.5 ft. Near RM 52, average bottom velocities at a river discharge of 550,000 cfs vary from 4.4 to 1.8 fps

for low and high tide, respectively. No saltwater density currents occur in the section of the river contained in the model.

8. The bed of the lower Columbia River consists primarily of clean sand and silt. The banks are of fairly firm clay except for rock in some reaches and are relatively stable. The Columbia River is not a heavy silt-carrying stream. Total movement of both suspended and bedload materials was estimated (1963) to range from 11.5 to 15 million cu yds per annum*. It has been estimated that about 3.5 million cu yds of the bedload result from the use of constriction works alone*.

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* Robert E. Hickson, "Columbia River Stabilization and Improvement for Navigation" Symposium on Channel Stabilization Problems, Technical Report No. 1, Volume 3, Committee on Channel Stabilization, Corps of Engineers, U.S. Army, June 1965.

PART II: THE MODEL

Description

9. A combined fixed- and movable-bed model was used to assess and optimize dredging requirements for the proposed 40- by 600-ft navigation channnel. The layout of the model is shown on plate 1. The movable-bed portion of the model extended from RM 53 to 65 and was confined to the main channel. Sufficient overbank topography, molded in concrete, was included to permit flow through sloughs and secondary channels and to extend beyond the limits of the record flood. The steeper banks adjacent to the movable-bed sections were also molded in concrete.

10. Topographic and hydrographic survey sheets were developed specially for this study. Overbank topography was mapped from aerial photographs taken during the period from June to September 1963. Hydrographic data for Walker Island slough, Fisher channel, and Bradbury slough were obtained in July and August 1963. The starting geometry for the riverbed was based on the 1961 predredge survey. Channel contours for this condition are shown on plates 2 and 3.

11. The movable-bed section of the model consisted of crushed coal having a specific gravity of 1.3 (saturated, surface dry) and a mean grain diameter of 2.1 mm. The particle size distribution of the coal used in the model is shown on plate 4. Templates, spaced approximately 3 ft apart (900-ft prototype), were suspended to the proper elevation from rails located along the concrete banks on each side of the movable-bed section.

Verification

12. Model verification consisted of a trial-and-error procedure in which the following factors were varied: bed slope, discharge, run time, rate and manner of introducing bed material, and stage at model gage 33A. The verification hydrographs used for all model tests are shown on plate 5. Observations of model bedload movement, surveys of model bed configurations, and water surface profiles assisted in the verification. Stages less than 4.1 ft (freshwater discharge of 172,500 cfs) were not reproduced because bed movement was insignificant at these lower stages. Dredging performed in the model during each hydrograph duplicated prototype dredging as closely as practicable. The location and quantity removed, time of removal, and disposition of spoil material along the channel banks were in accordance with prototype data shown on plates 6 through 11. The dredging periods are indicated on the verification hydrographs.

13. Tidal fluctuations were not reproduced in the model--instead, a fixed stage-discharge relationship was used in which the tidal effects through the model reach were averaged. Daily maximum and minimum water surface elevations obtained from automatic tide gage traces (Columbia River at Wauna, Oregon; RM 41.7) during the verification period of 1 Oct 1961 through 1 Mar 1964 were related to freshwater discharges for the same period. Figure A of plate 12 shows plots of the maximum, minimum, and mean stage-discharge relationships at the river gage with the elevation datum adjusted to mean sea level. The mean stage-

discharge curves are plotted in figure B of plate 12 for use in estimating model stage; the stages at RM 59.0 (the location of model reference gage 33A) was determined by interpolation.

14. During the preliminary phase of the model verification, observations were made of the movement of bed material, stability of the crushed-coal banks, pile dike design, flow directions in the upstream end of model, and flow distribution between the main channel and the secondary channels with both fixed-stage and simulated hydrograph methods of operation. Initial observations of bed material movement indicated that a reduction in the mean diameter of the crushed coal used in the model was necessary. The resulting grain-size distribution used for testing is shown on plate 4. All riverbanks molded in crushed coal were unstable with model slopes steeper than 1V:1H (1V:3H prototype) and at lesser slopes in some areas. These banks required stabilization with either 3/4-inch gravel or concrete. It was also necessary to stabilize some relatively flat areas subject to excessive or unnatural scour. The revised movable-bed limits are shown on plate 1.

15. Fixed-stage tests were made tc determine the required permeability of model pile dikes under various discharges. Permeability was adjusted to simulate local prototype scour and shoal areas adjacent to the dikes. A center-to-center spacing of 3/8 inch, for vertical piles was satisfactory at all discharges. The piles were alternately placed on the upstream and downstream side of the stringers.

16. Preliminary testing indicated that upstream approach-flow conditions in the model did not satisfactorily simulate prototype conditions due to the absence of a meander bend in the model coverage. Various systems of baffling and deflecting the inflow were attempted but there was no effective arrangement for all river stages.

17. Final verification tests were made to evaluate the adequacy of the adjustments. Model water surface profiles obtained during final verification and corresponding prototype profiles for selected river discharges are shown on plate 13. Model scour and fill maps for the 2.5-yr verification hydrograph are shown on plates 14 and 15. The corresponding prototype maps are shown on plates 16 and 17.

18. In general, results of the final verification tests indicated good agreement between model and prototype. Although some discrepancy existed between model and prototype bed contours, the important shoaling or scouring trends were in close agreement. Discrepancies in the vicinity of RM 55.3 and downstream from RM 54.3 existed but were not considered serious since normal depths in the navigation channel through this reach are well in excess of 45 ft. The portion of flow simulated by the model through Walker Island slough and Fisher channel was within 1 percent of that determined in the prototype for similar total discharges, but model discharge through Bradbury slough which required artificial roughness in its entrance for main channel conformity was from 2 to 3 percent lower than the prototype.

Scale Relationships

19. The models were built to model to prototype scale ratios of 1:300 horizontal (H) and 1:100 vertical (V). This produced a slope distortion of 3 to 1, providing a steeper gradient to facilitate movement of the crushed-coal bed material. Based upon the horizontal and vertical scales, the following scale relationships apply in the study: area equals 1:90,000 and volume equals 1:9,000,000. The time and discharge scales were determined empirically in verification of the bed movement in the model as these quantities do not scale according to Froudian laws of similarity.

20. The following relationships were determined from movable-bed model verifications tests:

a. Discharge: Initially, the model discharge scale was based upon that required to simulate prototype river stages in the model. The initial scale resulted in excessive movement at the high stage and insufficient movement at the low stage. Adjustments were made to the discharge scale during model verification based on the relative movement of model bed material at various river stages and on the development of scour and fill patterns required to reproduce prototype conditions. The final relationship was a variable scale (plate 18).

b. Rate of bedload introduction: Prototype bedload discharge data through the model reach was not available; therefore, the rate and manner of introducing material at the upstream end of the movable-bed section were determined during the verification tests. Consideration was given to (1) the rate of

material movement through the upstream end of the model, (2) local movement in the model necessary to produce the desired bed patterns, and (3) the amount of material reaching the model tailbay. Plate 19 shows the bedload introduction rates in relation to river stage.

c. Time: The time scale was originally set at 5 minutes of model time for 1 prototype day based on experience with similar models at other hydraulic laboratories. However, verification tests indicated that better agreement with prototype shoaling patterns was obtained with a time scale of 4.0 minutes of model time for 1 prototype day (1:360).

d. Slope: In addition to the geometric slope distortion of 3 provided by the model scales, the slope of the movable-bed portion of the models was steepened during model verification to 0.00717. This slope increase was required to provide the tractive forces necessary for acceptable simulation of prototype bed changes.

e. Stage: The river stage at gage 33A was determined from prototype data described in paragraph 13 and shown on plate 12. During verification tests, however, the datum was lowered 0.5 ft (0.005 ft in the model) to further facilitate movement of the bed material.

f. Other scale relationships: Other scale relationships relevant to the model are as follows:

Dimensions	Relationship
Surface Area	1:90,000
Cross Section Area	1:30,000
Volume	1:9,000,000

Appurtenances

21. Water was supplied to the models from a closed circulating system. Model discharges were measured by calibrated bellmouth orifices located in the supply line. Inflows from the tributaries of the Kalama and Cowlitz Rivers were measured by 60-degree V-notch weirs. Point gages were used for water surface measurements, and stage at the approximate center of the model gage 33A, RM 59.0) was controlled by an adjustable rectangular weir in the tailbay. Velocities in the model were measured with a midget Ott C-1 current meter.

22. Folded strips of window screen were used to simulate the roughness of brush and tree growth along the banks of the channels. Shipping docks simulated in the model were constructed of hardware cloth to produce the roughness of dock piling. The permeable pile dikes were constructed of No. 9 galvanized wire, and the vertical members were spaced to produce the required permeability in the model. A dolphin was placed on the riverward end of each dike simulating two three-pile clusters battered both upstream and downstream. A rock protection blanket was simulated at the base of each pile dike. The sounding apparatus used to

survey the movable bed consisted of a vertically graduated rod which was referenced to a portable horizontally graduated rail mounted on the template rails. The sounding rod was calibrated in 1-ft units (prototype) and had a swivel foot on the bottom which rested on but would not penetrate the coal bed.

Interpretation of Data

23. In interpreting and evaluating the model test results, the shoaling quantities may be used quantitatively to compare improvement plans in the model but cannot be transferred in a strictly quantitative manner to the prototype river channel. Shoaling data in the tabulations and graphs are presented in cubic yards for convenience, but in applying these quantities to the prototype, consideration must be given to the degree of verification obtained in the model. The time scale developed during the verification period was used in reproducing the test hydrograph, but it is not necessarily an accurate indication of the time required for model developments to occur in the prototype under similar conditions.

PART III: IMPROVEMENT PLANS AND RESULTS

24. A total of five improvement plans and one base condition were tested with the model. The base test was conducted using the existing 35-ft navigation channel alignment and existing corrective works. This test was conducted to determine if a reasonably stable bed would develop and to serve as a basis for evaluating the initial improvement plan (Plan 1), which consisted of the proposed 40-ft by 600-ft navigation channel with existing corrective works. The first plan then provided a basis for evaluating the effect of Plans 2 through 5 on maintenance dredging requirements. In all plans the navigation channel was dredged 5 ft deeper than the design depth.

25. For the base test and all improvement plan tests, the 1962 water year hydrograph shown on plate 5 was simulated. The hydrograph was repeated four times to assure the development of a reasonably stable bed. The navigation channel was not dredged between hydrographs. With Plans 2 through 5 the model bed did not reach a stable condition after testing with four hydrographs; therefore, these plans were tested with the hydrograph repeated 8 or 12 times. For this testing the bed was surveyed after every four repetitions of the hydrograph. The stage-discharge relationship, time scale, and rate and manner of introducing bed material developed during the verification of the model were used for all tests.

Base Test, 35-ft-Deep by 500-ft-Wide Navigation Channel

Description

26. The base test was initiated with the model bed molded to the configuation of the 1961 predredge prototype survey (plates 2 and 3). The 500-ft navigation channel was dredged throughout to a depth of 40 ft (design depth of 35 ft plus 5 ft of overdepth). Plates 20 and 21 show the channel contours after testing with four hydrographs and plates 22 and 23 show the resulting scour and fill patterns. The distribution of shoaling on each bar--Slaughters, Walker Island, Steller/Fisher, and Gull Island--is shown on plates 24 through 27. Total shoaling quantity existing was approximately 695,000 cu yds (table 1). Photograph 1 shows the surface flow patterns with a simulated freshwater discharge of 338,000 cfs.

Plan 1

Description

27. Plan 1 (plates 28 and 29) consisted of the 40- by 600-ft navigation channel and the corrective works that existed in the prototype during the October 1961 to March 1964 verification period. The purposes of this test were to determine the shoaling patterns and quantities that would occur in the enlarged channel without additions or changes to the existing corrective works and to provide a basis for comparison of subsequent improvement plans. The new channel alignment generally followed the 35-ft channel alignment and conformed to the locations of deepest water. The greatest difference in the two alignments occurred between RM 61.4 and 65.0 where the turning angle of one channel

bend was slightly increased and that of a second bend was reduced; a third channel bend was eliminated.

Results

28. Channel scour and fill patterns after four hydrographs are shown on plates 30 and 31. Shoaling distributions are shown graphically on plates 32 through 35. Photograph 2 shows the surface flow patterns during a simulated discharge of 338,000 cfs.

29. Overall shoaling for Plan 1 was 2.1 million cu yds compared with 0.7 million cu yds for the base test. Stella/Fisher bars received the greatest accumulation, with Slaughters, Walker Island/La Du, and Gull Island bars receiving lesser but significant quantities. A comparison of Plan 1 results with those of the 35-ft channel base test (table 1) shows that increasing the main channel cross section by enlarging the navigation channel caused a ten-fold increase in shoaling through Walker Island/La Du bars. Shoaling increases on the other bars, although not so dramatic as on the Walker Island/La Du bar, also were significant. The entire reach showed an increase in shoaling of 205 percent compared to the base test results. Shoaling on Slaughters bar totaled 623,500 cu yds with a more uniform shoaling distribution than that which occurred in the 35-ft channel base test (plate 34) with a reduced effect of pile dike 63.62 in evidence. With an accumulation of 567,600 cu yds, shoaling on Walker Island/La Du bars (plate 33) was evident along the entire bar except for a short reach in the vicinity of RM 62.25. Shoaling accumulations were heavy at the extreme upstream and downstream portions of the bar as in the 35-ft channel base

test. The large accumulation of 848,600 cu yds on Stella/Fisher bars was consistent with the continuous tendency for sediment buildup observed in the prototype. As shown on plate 34, the shoaling distribution pattern was similar to that observed in the 35-ft channel base test except that at RM 58.52 a much higher concentration of sediment occurred under Plan 1 conditions. Gull Island bar accumulated a total of 81,100 cu yds. This accumulation was distributed farther upstream and downstream along the bar than in the 35-ft base test, resulting in a 7 percent reduction in shoaling along the middle portion of the bar (plate 35).

Plan 2

Description

30. The test conditions for Plan 2 are shown on plates 36 and 37. Plan 2 retained all features of Plan 1 but additionally included 600 ft of pile dike extensions, a new 500-ft pile dike on Walker Island/La Du bars, and 5,200 ft of new dikes on Stella/Fisher bars. The dike additions, including the extensions, totaled 6,300 linear ft and were deployed as follows:

Bar	Washington Shore	Oregon Shore
Walker Island/La Du	62.91, 300 ft (extension)	61.88, 500 ft (new dike)
	62.59, 300 ft (extension)	
Stella/Fisher	58.31, 700 ft (new dike)	57.54, 500 ft (new dike)
	57.95, 600 ft (new dike)	57.32, 850 ft (new dike)
	57.57, 200 ft (new dike)	57.08, 800 ft (new dike)
		56.88, 900 ft (new dike)
		56.64, 650 ft (new dike)

Other additions to the model included the newly constructed alumina unloading pier of the Reynolds Metals Company and an adjacent 42-ft-deep dredged area at RM 63.5.

31. Dredged material was placed to elevation +15 CRD along the Oregon bank contiguous to Slaughters bar and Walker Island/La Du bars from the downstream end of Walker Island at RM 60.26 (Plate 36) to pile dike 63.62. Placement of this fill restricted the flow into Walker Island slough at the entrance and prevented flow into Walker Island slough between Lord and Walker Islands. Additional dredge disposal was placed along the Oregon bank contiguous to the Stella/Fisher bars and Gull Island bar between RM 54.60 and 57.48 (plate 37). This fill was placed to elevation +15 CRD from the Bradbury slough bifurcation downstream along Crims Island to restrict flow into the slough and to reduce the cross sectional area of the main channel.

32. Dredged material was placed on the Washington bank adjacent to the Walker Island/La Du and Stella/Fisher bars to elevation +15 CRD between RM 58.51 and 60.46. This restricted flow into Fisher channel and eliminated all flow between Fisher Island and the main channel. Additional fill was placed to elevation +22 CRD contiguous to Stella-Fisher bars on the Washington bank from RM 57.30 to 58.67.

Results

33. Scour and fill after eight hydrographs are shown on plates 38 and 39. Shoaling from RM 55 to 56 and from RM 63.6 to 64.2 would reduce navigation channel depths to approximately 35

ft. Shoaling distribution patterns in the proposed navigation channel for the four bars are shown on plates 40 through 43. Surface flow patterns during a simulated discharge of 338,000 cfs are shown in photograph 3. A summary of the total shoaling quantities and percentage changes from the Plan 1 results are shown in table 1. Compared to Plan 1 shoaling for the entire model reach increased 18 percent during the first 4-yr period but decreased 15 percent during the second 4-yr period.

34. Slaughters bar showed a shoaling increase in the navigation channel of 4 and 3 percent in the first and second 4-yr periods, respectively, as compared to Plan 1. The increased shoaling which occurred between RM 63.8 and 64.2 was attributed to the constriction at the entrance to Walker Island slough. The distribution of the shoaling throughout the bar was similar to the distribution with Plan 1 except from RM 63.3 to 63.6. The increased accumulation of deposits in the navigation channel in the vicinity of RM 63.3 at the end of the fourth hydrograph can be attributed to the increased cross sectional area as a result of the dredging activity at the Reynolds Metals Company unloading pier. This shoaling was also compounded by the heavier scour that occurred immediately upstream of the end of pile dike 63.62, which was rendered impermeable by disposal fill. Shoaling at RM 63.3 to 63.4 was noticeably reduced at the end of the eighth hydrograph, however. Plate 38 and table 41 show that during both the first and second 4-yr periods the shoaling distribution in the navigation channel changed without an appreciable change in total quantities.

35. The modifications made for Plan 2 were most effective in the Walker Island/La Du bars area. The sediment accumulation which developed in the navigation channel with Plan 1 was reduced by 54 and 79 percent in the first and second 4-yr periods, respectively. At the end of the first 4-yr period, this reduction was most significant near the downstream end of Walker Island (RM 60.0 to 60.6) and extended upstream to RM 62.0 (plate 41). At the end of the eighth hydrograph, a further decrease in shoaling was generally indicated throughout the bars with the greatest reductions occurring at RM 63.1 and between RM 59.7 and 60.4. Except for the extreme upstream 500 ft of these bars, all navigation channel cross sections had segments with depths of 45 ft or more. These changes can be attributed to the constrictive effect of the disposal fill placed along the Oregon bank from the upstream end of Lord Island to the downstream end of Walker Island and on the Washington shore at the Fisher channel bifurcation. Shoaling at the entrance to Fisher channel (RM 61.0) increased considerably from the Plan 1 results. Model velocities recorded early in the test at RM 61.1 during simulated flows of 338,000 and 450,000 cfs showed an average increase across the entire section of 12.4 percent from the Plan 1 velocities. In the navigation channel the average increase was 7.4 percent.

36. Stella/Fisher bars showed the least improvement resulting from the implementation of Plan 2. In this case, deposition in the navigation channel showed an increase of 82 and 18 percent in the first and second 4-yr periods, respectively, as compared to that observed with Plan 1. During the initial 4-yr period,

shoaling was substantially increased--relative to Plan 1 shoaling--from RM 58.3 to 59.6, RM 56.9 to 57.7, and at RM 56.5. This was largely due to the increased sediment movement from Walker Island/La Du bars located immediately upstream. Section average velocity measured early in the test for simulated flows of 338,000 and 450,000 cfs at RM 58.7 showed an increase of 5.4 percent from that of Plan 1. In the navigation channel the average increase was 8.3 percent. At RM 59.2 section average velocity showed an increase of 2.0 percent, and the navigation-channel average velocity increased by 5.7 percent.

37. Because the rate of transport of bedload to RM 58.5 exceeded the sediment-transport capacity at that point a deposit formed in the navigation channel early in the test. Rapid accretion on this shoal caused migration of the upstream face to about RM 59.8 by the end of the fourth hydrograph. During the second 4-yr period following navigation channel dredging to project depth, shoaling was greatly reduced through this area and a slight improvement over the Plan 1 results was observed (plate 40). Placement of the constrictive disposal fill along the Washington bank opposite RM 59.0 was not effective in maintaining movement of sediment entering this area due to the increased volume of bedload that resulted from excessive erosion upstream on Walker Island/La Du bars. In the vicinity of RM 58.2, shoaling remained nominal throughout the test and was virtually the same as that in Plan 1. From RM 57.0 to 57.7, navigation channel shoaling during the first 4-yr period increased considerably from Plan 1 quantities. This shoaling persisted at approximately the

same location and in the same quantity during the last 4-yr period of the test. At RM 56.6 the shoaling increase which occurred during the first 4-yr period was not apparent during the last 4-yr period.

38. Gull Island bar showed the second greatest improvement from Plan 1. Shoaling in the navigation channel was reduced by 38 and 59 percent during the first and second 4-yr periods, respectively, as compared to Plan 1. The shoaling distribution graph (plate 41) shows that the improvement generally occurs throughout the bar. Increased flow in the main channel was attributed to the restriction of the entrance to Bradbury slough, to the constrictive effects of the disposal fill on Crims Island, and to some extent by the flow deflection provided by the constrictive works at the exit to Fisher channel. Consequently, shoaling from RM 55.5 to 55.9 was reduced and material was displaced downstream (RM 54.5 to 55.4) and outside the navigation channel. The bedload that moved downstream of RM 55.0 passed further to the left than it did in Plan 1 and was transported through the problem area. Deposits in the navigation channel upstream of RM 55.0 were well below project depths and would present no maintenance problems. Plan 2 was especially effective during the first 4-yr period at the extreme downstream end of the disposal fill on Crims Island (RM 54.6). Section average velocity measured at RM 54.3 during simulated discharges of 338,000 and 450,000 cfs increased 3.4 percent from that of Plan 1 while average velocity in the navigation channel decreased 0.47 percent.

Plan 3

Description

39. The test configuration for Plan 3 is shown on plates 44 and 45. Test conditions for Slaughters bar and Walker Island/La Du bars remained the same as those in Plan 2. The changes from Plan 3 included the closure of the upstream entrance to Bradbury slough and the riverward extension of the five pile dikes added in Plan 2 along Crims Island downstream from the slough entrance. In Plan 2 the following pile dikes were increased in length: dike 56.64 from 650 to 1400 ft, dike 56.88 from 900 to 1580 ft, dike 57.08 from 800 to 1380 ft, dike 57.32 from 850 to 1350 ft, and dike 57.54 from 500 to 900 ft. On the Washington shore, existing pile dike 57.19 was extended 180 ft riverward so that its riverward end was aligned with the ends of the adjacent upstream and downstream dikes. On Gull Island bar, the disposal fill on Crims Island was moved shoreward between RM 55.0 and 55.5 to reduce the constrictive effects of the fill.

Results

40. Scour and fill conditions after eight hydrographs are shown on plates 46 and 47. Shoaling distribution is shown on plates 48 through 51. Surface flow patterns with a fresh-water discharge of 338,000 cfs are shown on photograph 4.

41. Since test conditions on Slaughters bar and Walker Island/La Du bars were the same as those for Plan 2, the total quantities of shoaling were also similar for the two plans. The distribution of shoaled material for the two reaches did vary from Plan 2 to 3, however. Since Slaughters bar is near the

model forebay and bed-material introduction area, the observed differences in the distribution are probably due to variations in model operating conditions. On Walker Island/La Du bars the shoaling distribution differed from that of Plan 2 primarily because of backwater effects created by closing Bradbury slough and extending the dikes on Crims Island downstream from the slough.

42. On Stella/Fisher bars, Plan 3 shoaling in the navigation channel was 57 percent higher than that in Plan 1 during the first test period (table 1). Upon completion of the second test period, Plan 3 shoaling was 40 percent less than the Plan 1 4-yr total--this was a substantial reduction from Plan 2 quantities. The effectiveness of the Bradbury slough closure and the lower dikes of Plan 3 was evident by comparing the scour and fill which had occurred with Plan 2. More bed material moved through this reach and into the Gull Island bar area downstream indicating that the control works caused an increased bedload transport rate.

43. Due to the disturbance of previously stable upstream areas, Gull Island bar was subjected to an influx of bed material early in the test--particularly on the lower Stella/Fisher bars. Shoaling in the navigation channel by the end of the first test period was 73 percent greater than occurred with Plan 1. With channel dredging to elevation -45 CRD, shoaling during the second test period increased by 97 percent over that observed with the Plan 1 4-yr total (table 1). Any beneficial effect of the

channel constriction on Gull Island bar was overshadowed by the effects of upstream control works in Plan 3.

Plan 4

Description

44. The test conditions for Plan 4 (plates 52 and 53) were the same as those in Plan 3 except for that of the river reach adjacent to Fisher Island (RM 58.5 to 60.5). In order to relieve the constriction of the main channel near the upstream end of Fisher Island, dike 59.85 was shortened 165 ft, dike 60.21 was shortened 320 ft, and dike 60.51 was shortened 300 ft. Sections of the riverbed adjacent to pile dikes 59.85 and 60.21--which were fixed during Plan 3--were molded in coal for Plan 4. On the downstream end of Fisher Island, the disposal fill was moved 200 ft riverward. To stabilize this fill and to increase local scouring, the three 600-ft pile dikes--58.59, 58.93, and 59.27--were projected riverward through the disposal area.

Results

45. Scour and fill after testing with twelve hydrographs are shown on plates 54 and 55. Shoaling distributions in the navigation channel for the four bars are graphically shown on plates 56 through 59. Table 1 shows that Plan 4 had an overall shoaling increase over Plan 1 of 24 percent after the first four hydrographs, a 13-percent reduction after the second four hydrographs, and a 35-percent reduction after the last four hydrographs. Surface flow patterns with a fresh-water discharge of 338,000 cfs are shown on photograph 5. The change in model average velocity in the main channel and navigation channel for

Plans 2 through 4 as compared to Plan 1 are given on table 2. Plan 4 had generally higher velocities at all measuring locations.

46. Lower Slaughters bar had approximately the same overall shoaling quantity in the navigation channel as that which occurred with Plans 1 through 3 during the corresponding test periods. The variations in the distribution patterns apparent in each instance are insignificant and primarily attributable to model conditions and operating procedures. On Walker Island/La Du bars, the overall reductions in navigation channel shoaling were 25, 61, and 64 percent from the Plan 1 4-yr total for each successive 4-yr test period.

47. Shoaling in the navigation channel on Stella/Fisher bars increased 71 percent from the Plan 1 total during the initial test period. The navigation channel was dredged to elevation -45 CRD between test periods. After the third test period the total accumulation on the bar was 54 percent less than occurred with Plan 1. As in Plan 3, Gull Island bar was subjected to an influx of bed material early in the test because equilibrium conditions were disturbed on the upstream reaches of the model. Shoaling in the navigation channel by the end of the first test period was 54 percent higher than that occurring in Plan 1 and increased as the test progressed.

Plan 5

Description

48. The test conditions for Plan 5 are shown on plates 60 and 61. Compared to previous plans, the major change was realignment of the navigation channel from RM 56.1 to 59.2 on Stella/Fisher bars. It was anticipated that shoaling might be reduced if the channel were closer to the proposed pile dikes projecting from Crims Island; therefore, the Stella/Fisher tangent was turned 17.75° so that at RM 56.45 the navigation channel was 300 ft to the left (or south) of the original alignment. All disposal areas remained the same as those in the previous test (Plan 4). Three pile dikes--58.59, 58.93, and 59.27--extending from the disposal fill in Plan 4 were eliminated in Plan 5 due to objections by local fishing interests. All other proposed pile dikes remained the same as those in Plans 3 and 4. Sections of the riverbed adjacent to Fisher Island (RM 59.35 to 60.25) which were fixed with gravel during the testing of Plans 1 to 3 were molded in coal as in Plan 4.

Results

49. Scour and fill conditions following testing with twelve hydrographs are shown on plates 62 and 63. Shoaling distribution for Stella/Fisher and Gull Island bars is graphically shown on plates 64 and 65. Surface flow patterns during a simulated freshwater discharge of 338,000 cfs are shown on photograph 6. Shoaling quantities for all the plans and percentage changes from the 4-yr quantities of Plan 1 are summarized in table 1. Gull

Island bar was subjected to an influx of bed material from upstream sources; this was similar to conditions existing with Plans 3 and 4.

50. Accumulated sediment volume in the navigation channel with Plan 5 was 21 percent less than that with Plan 3 during the initial 4 years of the test but was 28 percent higher than with Plan 3 during the second 4-yr period. A comparison of the shoaling distributions in the navigation channel (plate 66) shows that in the vicinity of the mouth of Fisher channel shoaling with Plan 5 was reduced from that with Plan 3 (from RM 57.53 to 58.35) and with Plan 4 (from RM 57.37 to 58.18). However, the channel immediately upstream and downstream of these reaches experienced heavier shoaling with Plan 5 than with either Plan 3 or 4; the greatest increase occurred in the vicinity of RM 58.4. Heavier scour occurred outside and to the right of the navigation channel (RM 59.35 to 60.25) than with Plan 4, but bedload accumulation in the adjacent navigation channel was about the same in both tests. Testing with Plan 3, in which the bed was fixed in this area, indicated a trend toward less shoaling in the adjacent navigation channel. The average velocity recorded early in Plan 5 testing for simulated flows of 338,000 and 450,000 cfs at RM 56.9 increased 4 percent from that of Plan 1, which is 3 percent lower than that recorded with Plan 3. Average velocity at RM 58.7 was 8 percent higher than that with Plan 1 and 5 percent higher than that with Plan 3.

PART IV: SUMMARY

51. The results of the model testing program have been presented as a basis for comparison of the performance of certain proposed plans for navigation channel improvement. The model simulation of prototype velocity distribution, bedload transport, and scouring and shoaling tendencies was adequate to provide reliable information about the relative changes in these quantities from plan to plan. The test results are thus useful for the development of strategies for shoaling reduction and mitigation of any potentially undesirable impact upon the river system. However, given the nature of uncertainties in the model verification procedures--which are to some degree inherent in distorted-scale, movable-bed modeling techniques--the model results should not be construed to be accurate indicators of the absolute values of velocity, bedload transport rate, or shoaling volume which would occur in the prototype for the simulated flows.

52. Table 1 summarizes the shoaling quantities which occurred for each bar and for all bars combined. Overall, Plans 3 and 4 had the overall greatest shoaling reductions under stabilized conditions. At the end of the first test period, shoaling relative to Plan 1 increased 13 and 24 percent for Plans 3 and 4, respectively, and by the end of the second test period the plans had respective reductions of 32 and 13 percent. After the third test period for Plan 4, the reduction was 35 percent. Based on the model observations and the additional dredging required for Plan 5--467,000 cu yds more than for Plans 1 through 4--(table 3

lists the construction dredging requirements for Plans 1 through 5), Plans 3 and 4 appear to be the most effective plans tested in the model.

TABLE 1

SUMMARY OF SHOALING QUANTITIES, 40- X 600-FT CHANNEL
PLANS 1 TO 5

Plan No.	Bars								Totals	
	Slaughters		Walker I.-La Du		Stella-Fisher		Gull-Island			
	Cu Yds	% Change From Plan 1	Cu Yds	% Change From Plan 1	Cu Yds	% Change From Plan 1	Cu Yds	% Change From Plan 1	Cu Yds	% Change From Plan 1
35-Ft Channel (Base Test)	353,000		58,700		245,600		37,300		694,600	
40-Ft Channel (Base Test) 1	623,500		567,600		848,600		81,100		2,120,800	
2	647,300	+4	258,300	-54	1,545,900	+82	50,600	-38	2,502,100	+18
(5-8 Yrs)	641,800	+3	117,200	-79	999,500	+18	33,600	-59	1,792,100	-15
3	629,700	+1	295,600	-48	1,330,200	+57	140,400	+73	2,395,900	+13
(5-8 Yrs)	617,700	-1	151,000	-73	510,100	-40	159,700	+97	1,438,500	-32
4	632,800	+1	428,300	-25	1,453,900	+71	124,600	+54	2,639,600	+24
(5-8 Yrs)	617,500	-1	221,000	-61	852,100	0	161,400	+99	1,852,000	-13
(9-12 Yrs)	609,100	-2	205,300	-64	386,600	-54	174,900	+116	1,375,900	-35
5					1,102,800	+30	65,000	-20		
(5-8 Yrs)					710,100	-16	153,300	+89		
(9-12 Yrs)					598,500	-29	128,300	+58		

NOTES:
1. Quantities shown are shoaling in the navigation channel above elevation -45 CRD (40 ft plus 5-ft overdepth).
2. Percentages are based on the 4-yr shoaling quantities in plan 1 (40-ft channel base test).
3. Shoaling quantities are for the initial 4-year hydrographs except those indicated.
4. Navigation channel was dredged to 45-ft depth prior to 5th hydrograph in 8-year tests, and prior to 5th and 9th hydrographs in 12-year tests.

TABLE 1

TABLE 2

CHANGE IN MODEL VELOCITIES
[illegible]- X [illegible]-Ft Channel

Plans [illegible] To 4

[illegible]	River Mile	Mean Change in Per Cent of Base Test Velocity					
		Main Channel			Navigation Channel Only		
		Plan [illegible]	Plan [illegible]	Plan 4	Plan 2	Plan 3	Plan 4
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	+7	[illegible]	+7
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	+11	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	+7	[illegible]	[illegible]	+17	[illegible]

[illegible]: 1. [illegible] in per cent of plan [illegible] [illegible] an average for [illegible] discharges [illegible] cfs.

[illegible]. [illegible]-depth.

TABLE 3

CONSTRUCTION DREDGING REQUIREMENTS, 40- X 600-FT CHANNEL

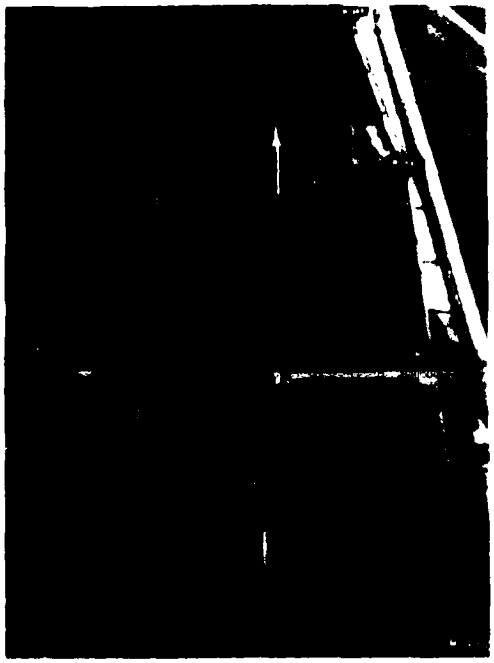
PLANS 1 TO 5

Plan No.	Construction Dredging Requirements in Cubic Yards				
	Slaughters Bar	Walker Island -La Du Bars	Stella-Fisher Bars	Gull Island Bar	Total
1					
2			2,112,300		
3	1,327,900*	1,274,000		189,000	4,903,200
4					
5			2,579,900		5,370,800

* Does not include dredging upstream of mile 64.4.

NOTES: 1. Quantities are based on the 1961 predredge survey.

2. Construction dredging was to elev -45 CRD.



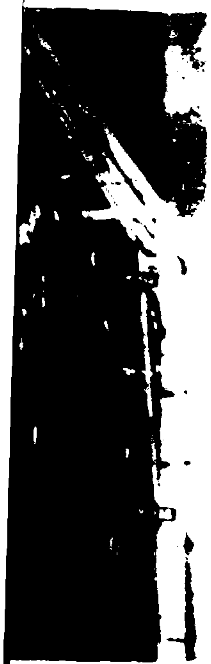
River Mile 65.0 to 63.3

River Mile 63.8 to 61.7

River Mile 60.6 to 59.0

River Mile 59.2 to 56.7

Photograph 1. Surface flow patterns f
navigation channel), fr



to 61.7

River Mile 62.7 to 61.1

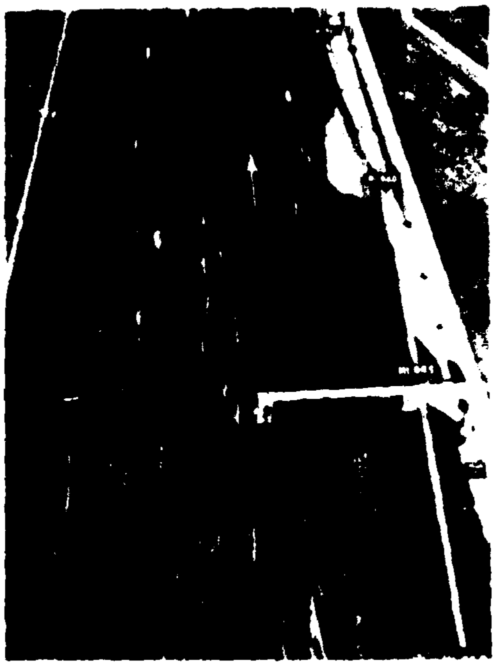
River Mile 61.8 to 60.1

to 56.7

River Mile 56.8 to 54.5

River Mile 54.6 to 53.0

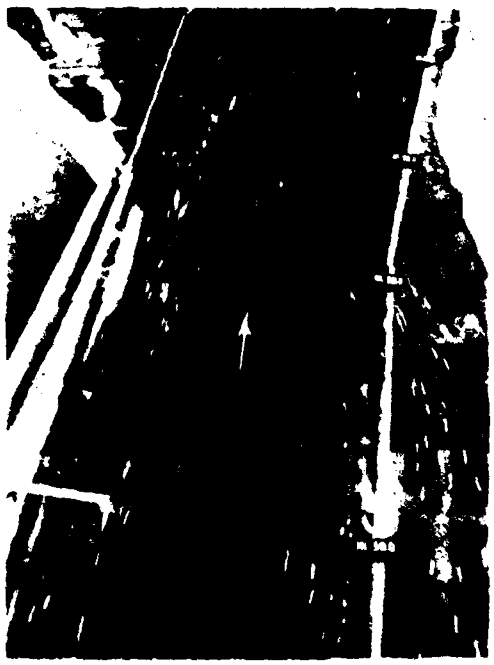
Surface f.ow patterns for base test (35 ft x 500 ft navigation channel), freshwater discharge 338,000 cfs.



River Mile 65.0 to 63.3

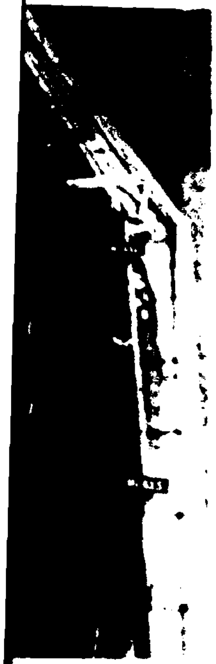
River Mile 63.8 to 61.7

River Mile 60.6 to 59.0



River Mile 59.2 to 56.7

Photograph 2. Surface flow pattern
freshwater discharge



to 61.7

River Mile 62.7 to 61.1

River Mile 61.8 to 60.1

to 56.7

River Mile 56.8 to 54.5

River Mile 54.6 to 53.0

2. Surface flow patterns for improvement plan 1, freshwater discharge 338,000 cfs.

River Mile 65.0 to 63.3

River Mile 63.8 to 61.7

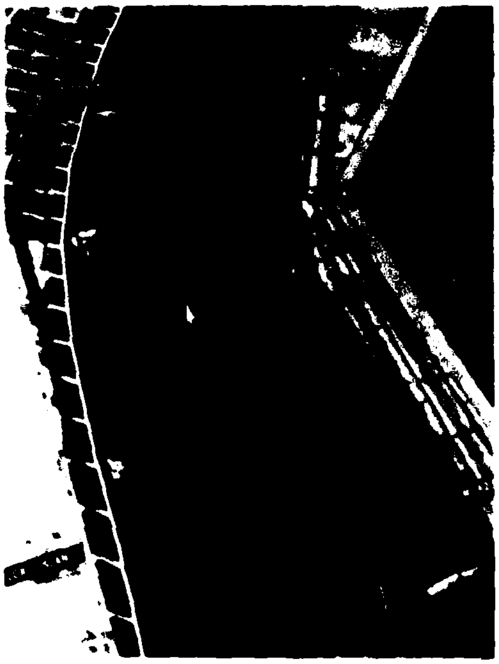
R

River Mile 60.6 to 59.0

River Mile 59.2 to 56.7

Photograph 3. Surface flow patterns 1
freshwater discharge 3:

to 61.7



River Mile 62.7 to 61.1

River Mile 61.8 to 60.1

2 to 56.7

River Mile 56.8 to 54.5

River Mile 54.6 to 53.0

3. Surface flow patterns for improvement plan 2, freshwater discharge 338,000 cfs.

River Mile 65.0 to 63.3

River Mile 63.8 to 61.7

River

River Mile 60.6 to 59.0

River Mile 59.2 to 57.0

River

Photograph 4. Surface flow patterns for ı
freshwater discharge 338,00

o 61.7

River Mile 62.7 to 61.1

River Mile 61.6 to 59.5

o 57.0

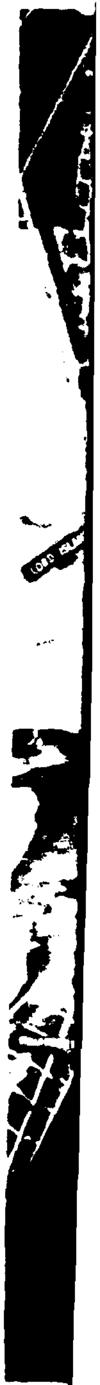
River Mile 56.8 to 54.5

River Mile 54.6 to 53.0

Surface flow patterns for improvement plan 3, freshwater discharge 338,000 cfs.

River Mile 65.0 to 63.3

River Mile 63.8 to 61.7



River Mile 60.6 to 59.0

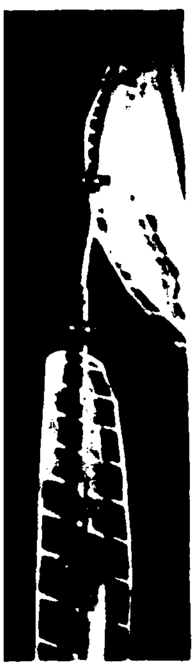
River Mile 59.2 to 57.0

Photograph 5. Surface flow patterns freshwater discharge

o 61.7

River Mile 62.7 to 61.1

River Mile 61.6 to 59.5

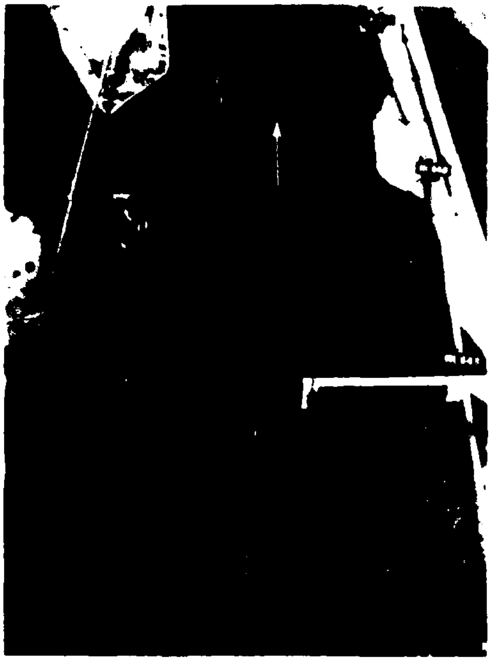


o 57.0

River Mile 56.8 to 54.5

River Mile 54.6 to 53.0

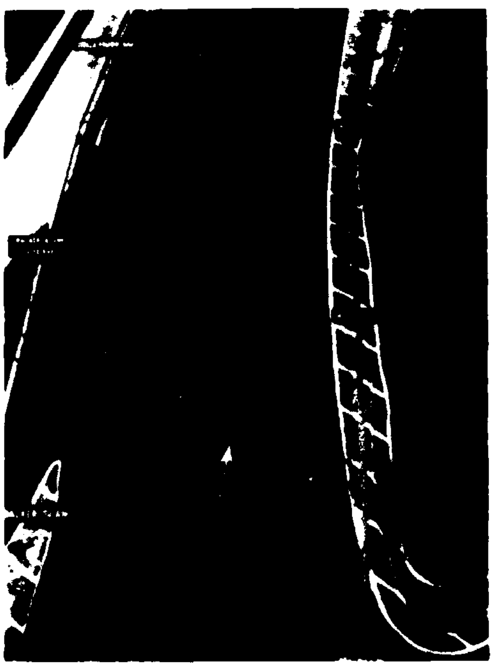
Surface flow patterns for improvement plan 4, freshwater discharge 338,000 cfs.



River Mile 65.0 to 63.3

River Mile 63.8 to 61.7

Ri



River Mile 60.6 to 59.0

River Mile 59.2 to 56.7

Ri

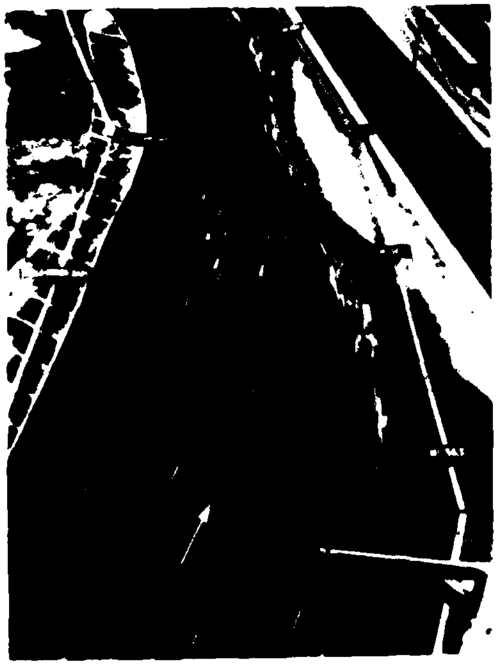
Photograph 6. Surface flow patterns fo
river discharge 338,000

to 61.7

River Mile 62.7 to 61.1

River Mile 61.8 to 60.1

to 56.7

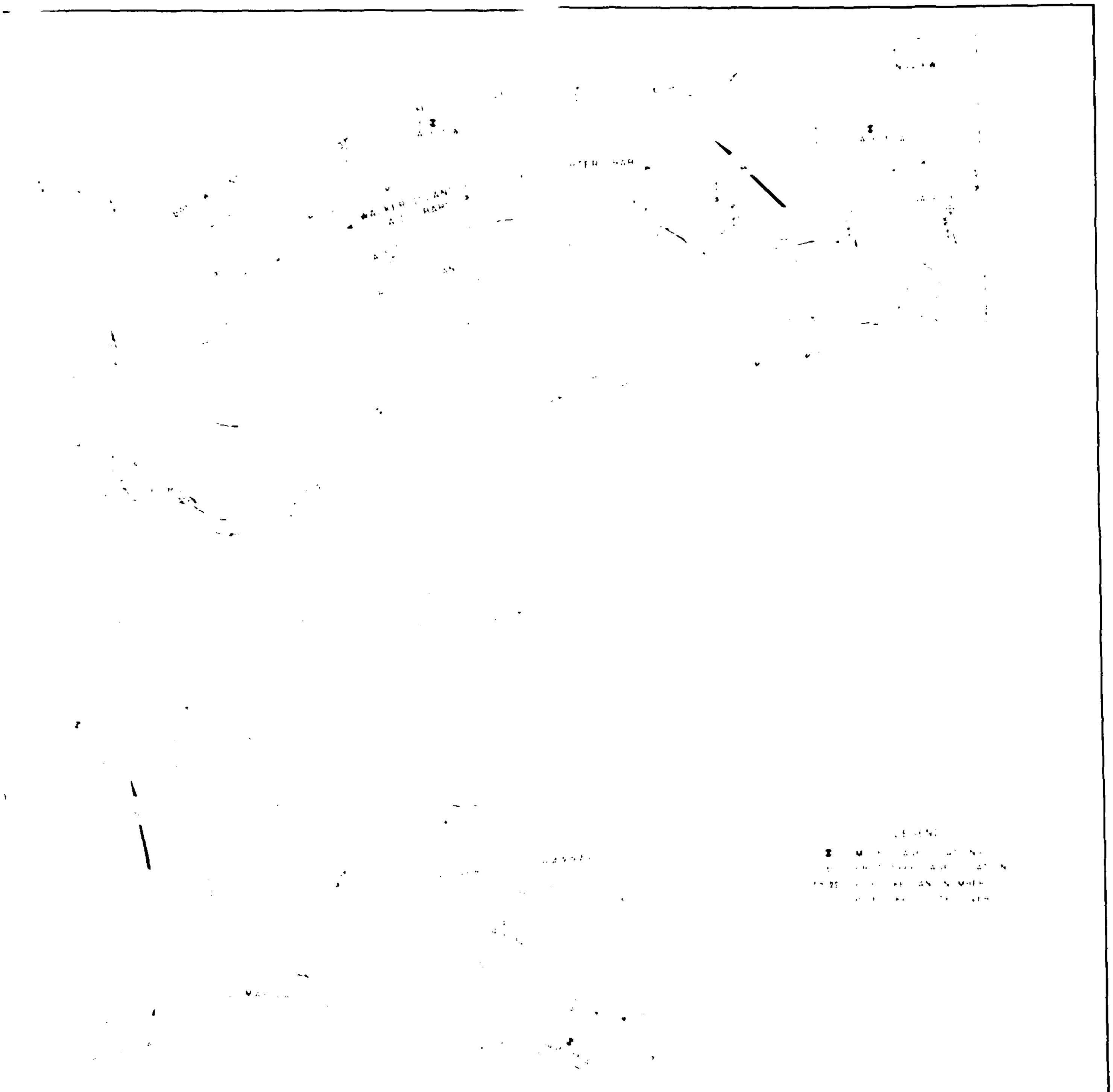


River Mile 56.8 to 54.5

River Mile 54.6 to 53.0

Surface flow patterns for improvement plan 5, river discharge 338,000 cfs.


BAR
BARS



MODEL LAYOUT

PLATE 1

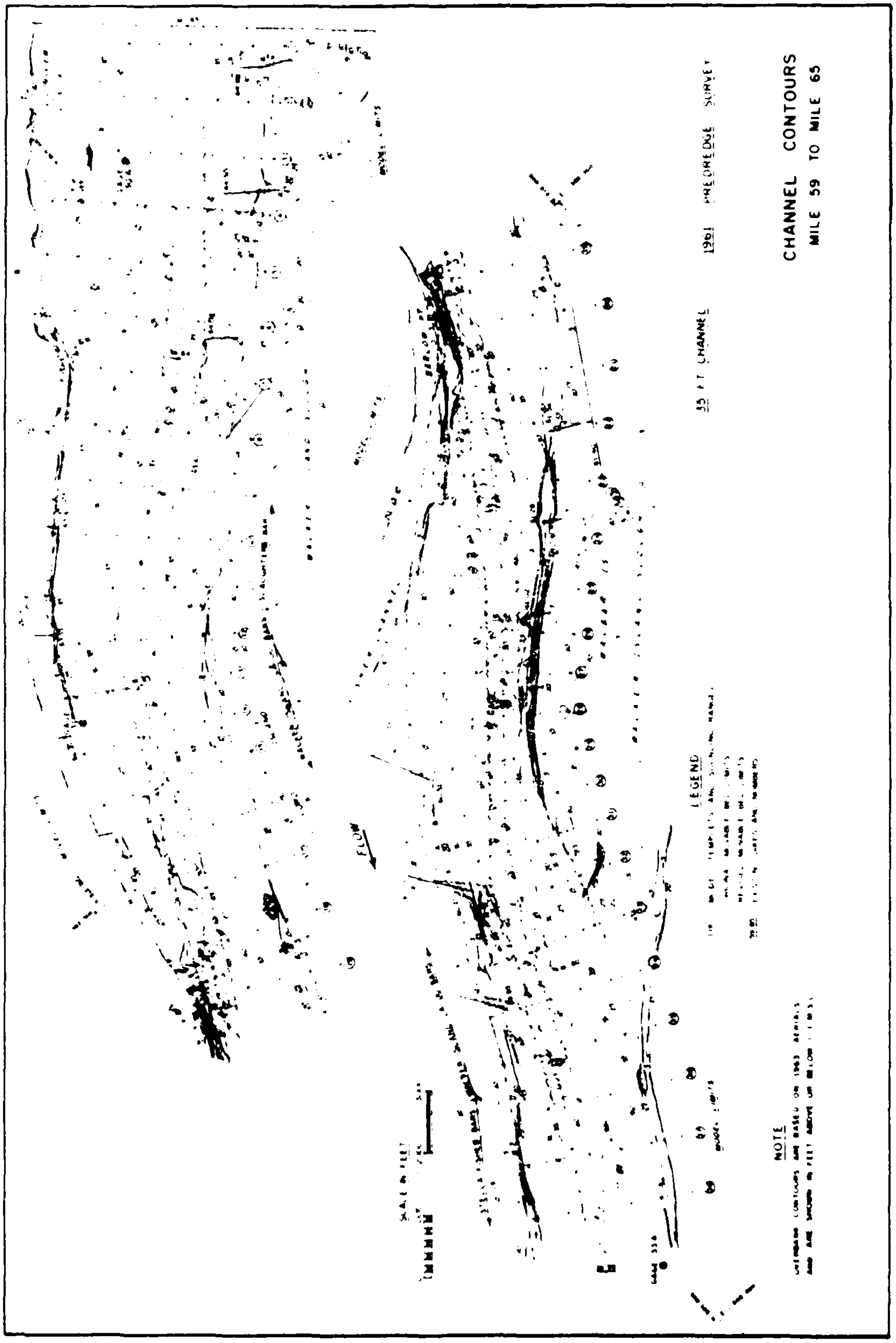
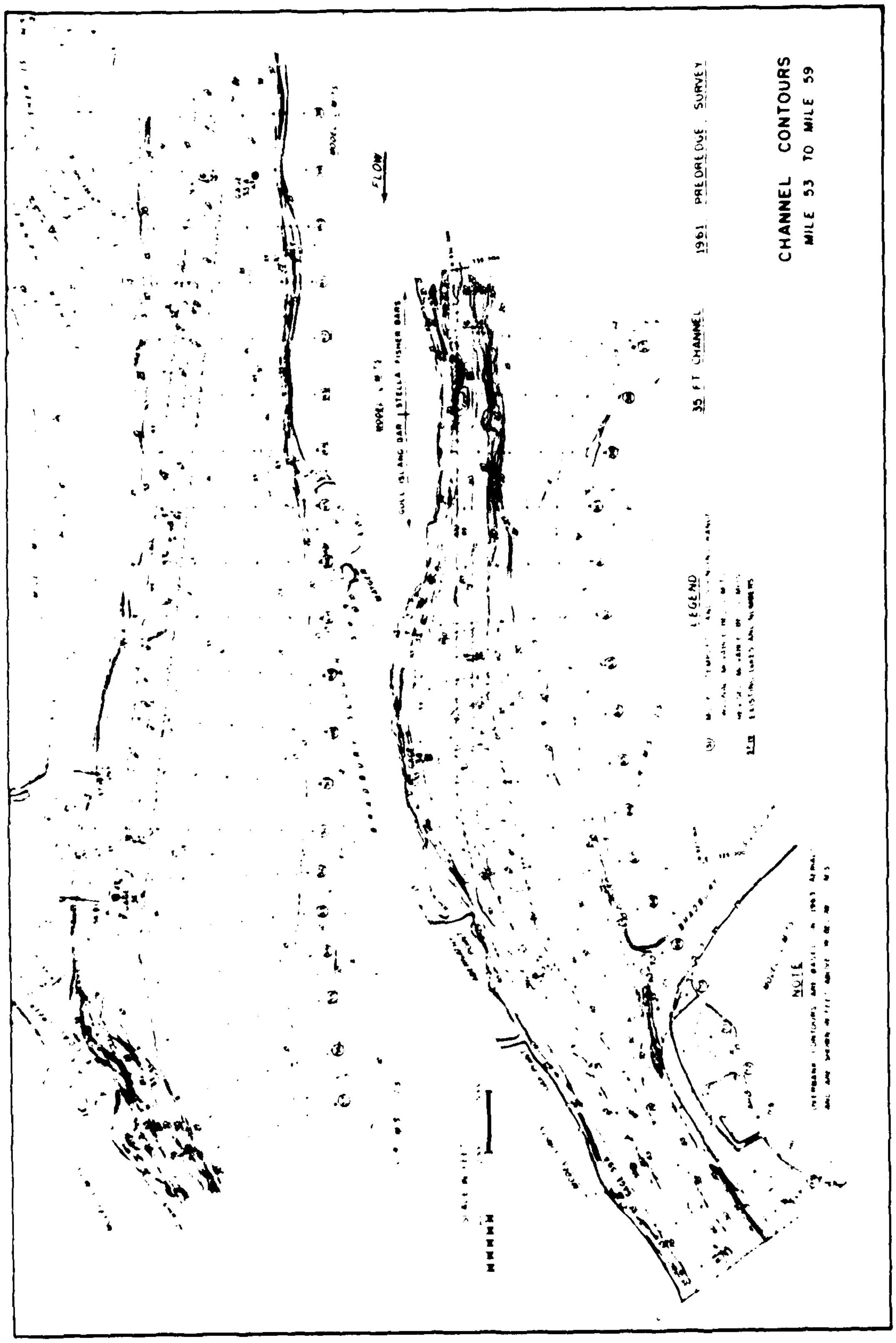
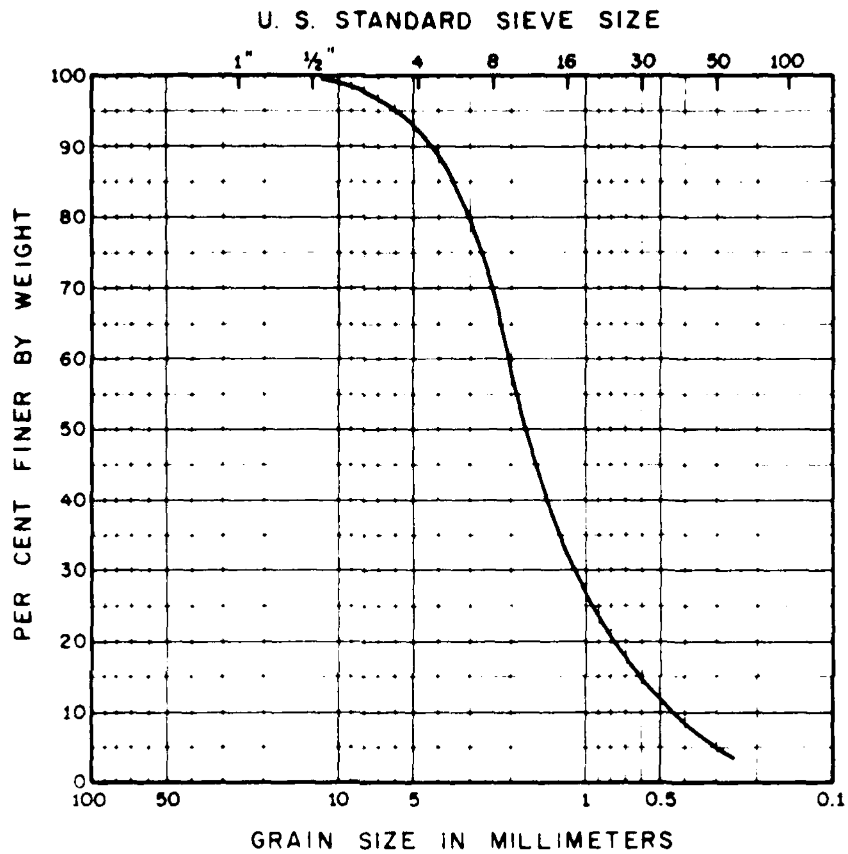

CHANNEL CONTOURS
MILE 59 TO MILE 65
35 FT CHANNEL
1961 PREDREDGE SURVEY
LEGEND
FLOW
SCALE IN FEET
NOTE

PLATE 2

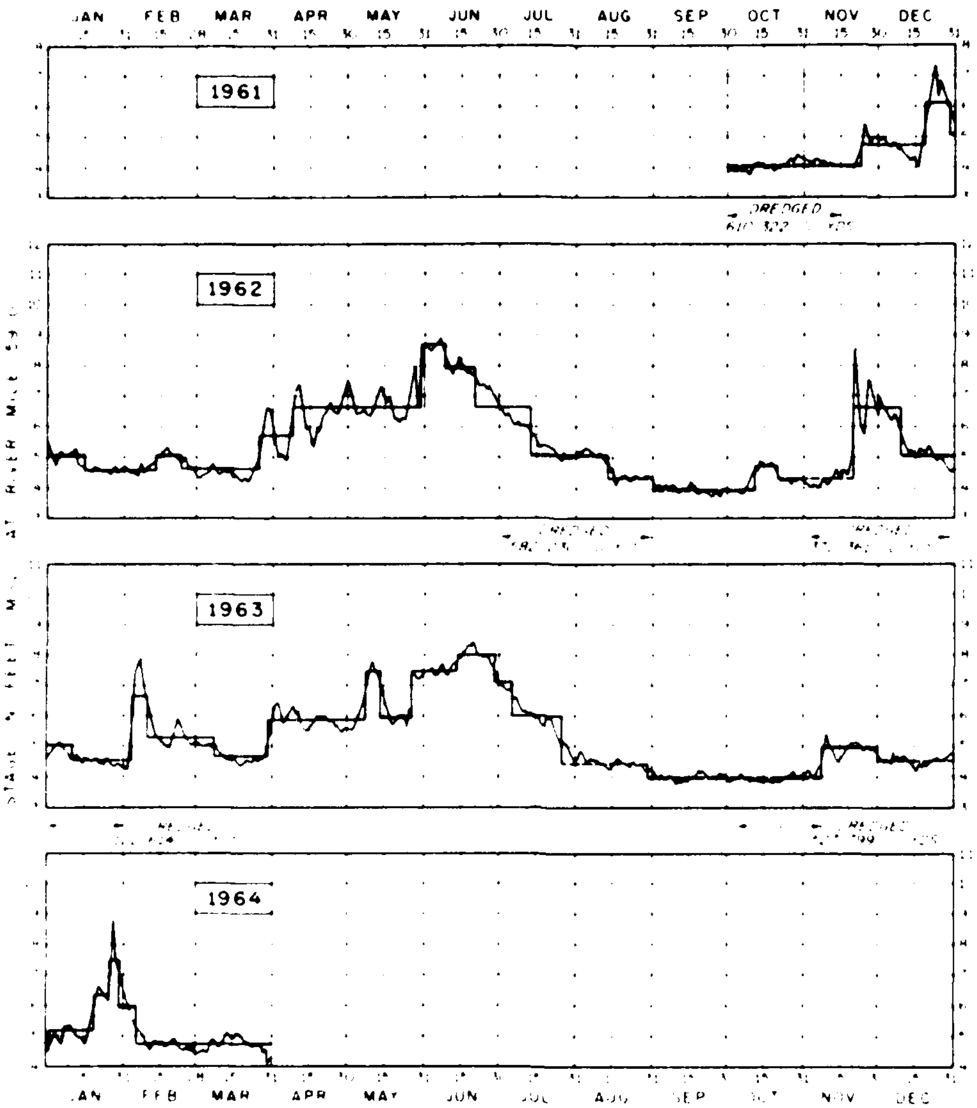


CHANNEL CONTOURS
MILE 53 TO MILE 59
1961 PREDREDGE SURVEY
35 FT CHANNEL
FLOW
LEGEND
NOTE

PLATE 3



GRAIN-SIZE DISTRIBUTION OF
MODEL BED MATERIAL



LEGEND

PROTOTYPE HYDROGRAPH

MODEL HYDROGRAPH

OMITTED IN MODEL OPERATION

VERIFICATION HYDROGRAPH
MILE 59.0

PLATE 5

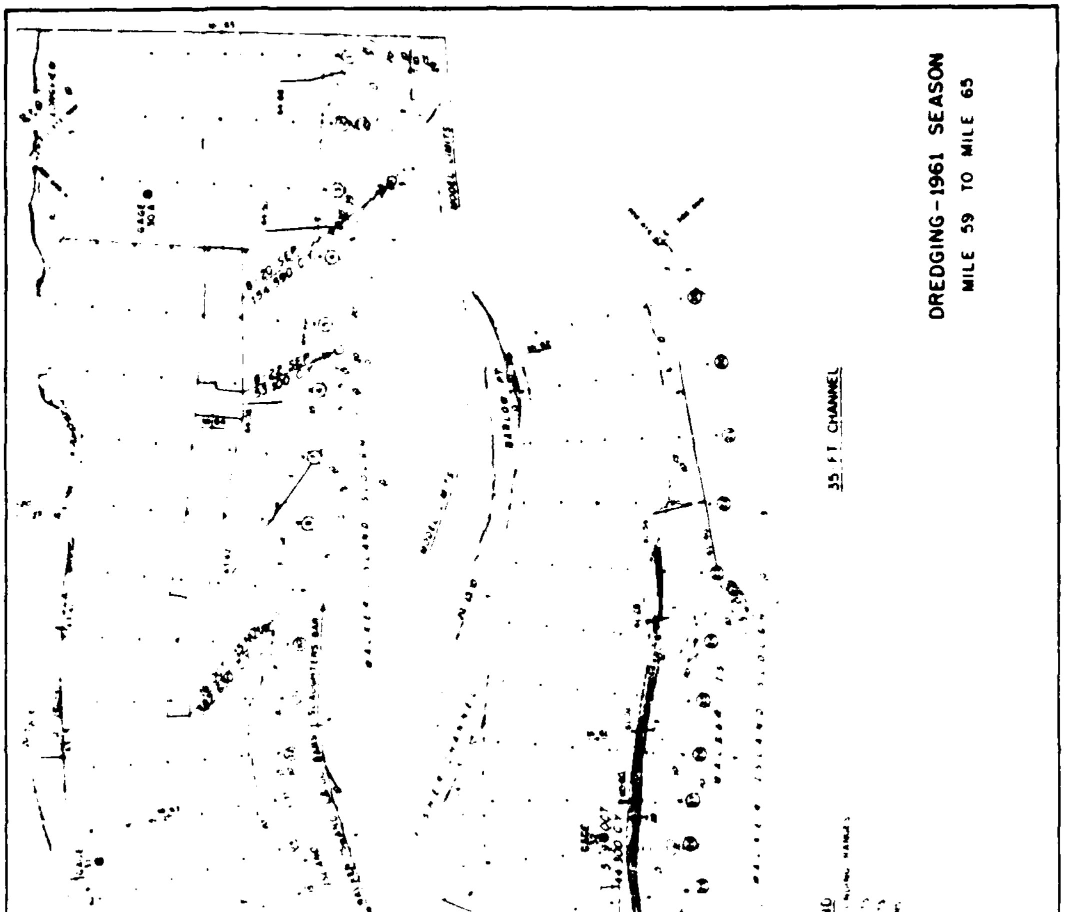

DREDGING-1961 SEASON
MILE 59 TO MILE 65
35 FT CHANNEL
LEGEND
NOTE
FLOW
SCALE IN FEET

PLATE 6

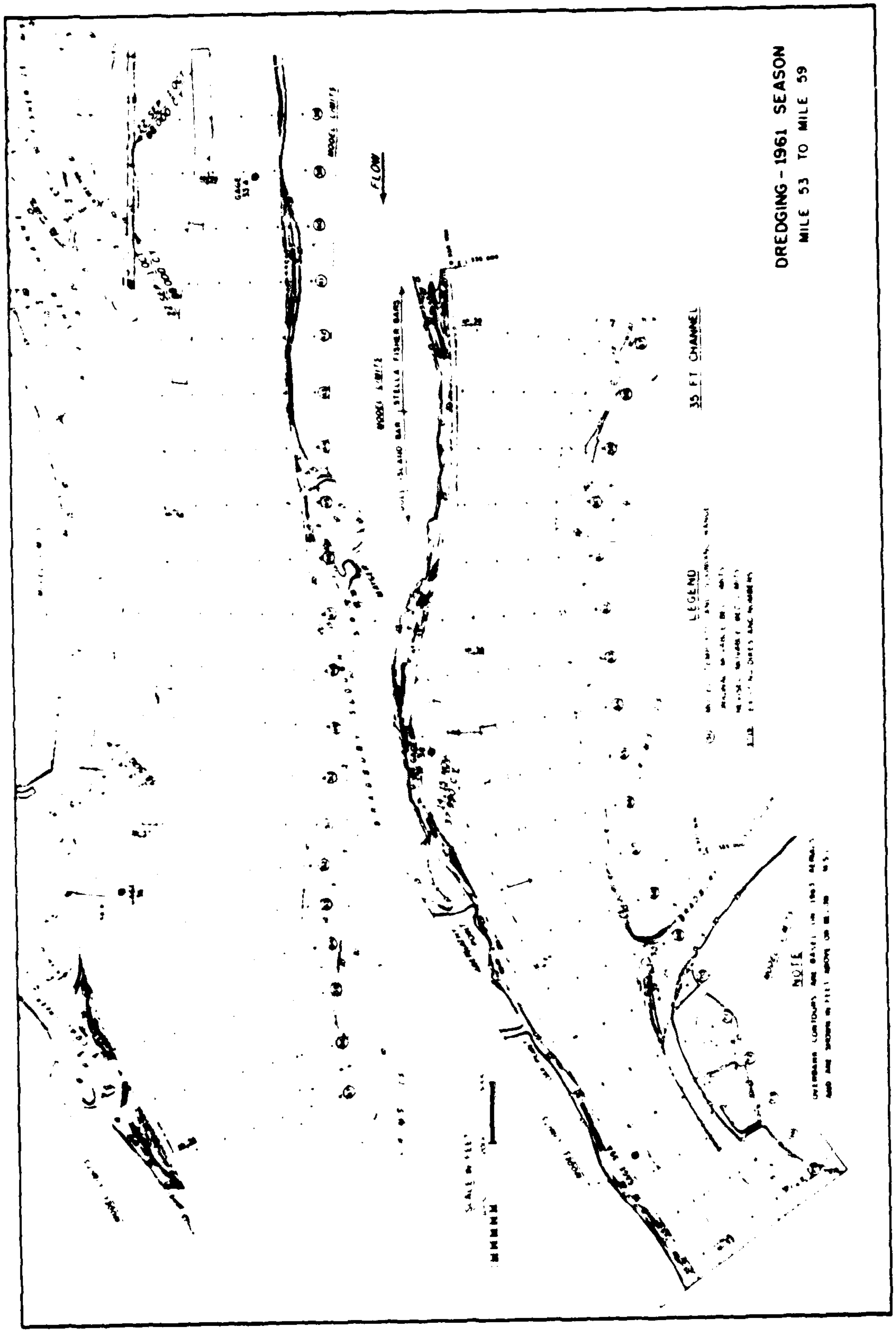

DREDGING - 1961 SEASON
MILE 53 TO MILE 59
FLOW
35 FT CHANNEL
LEGEND
NOTE

PLATE 7

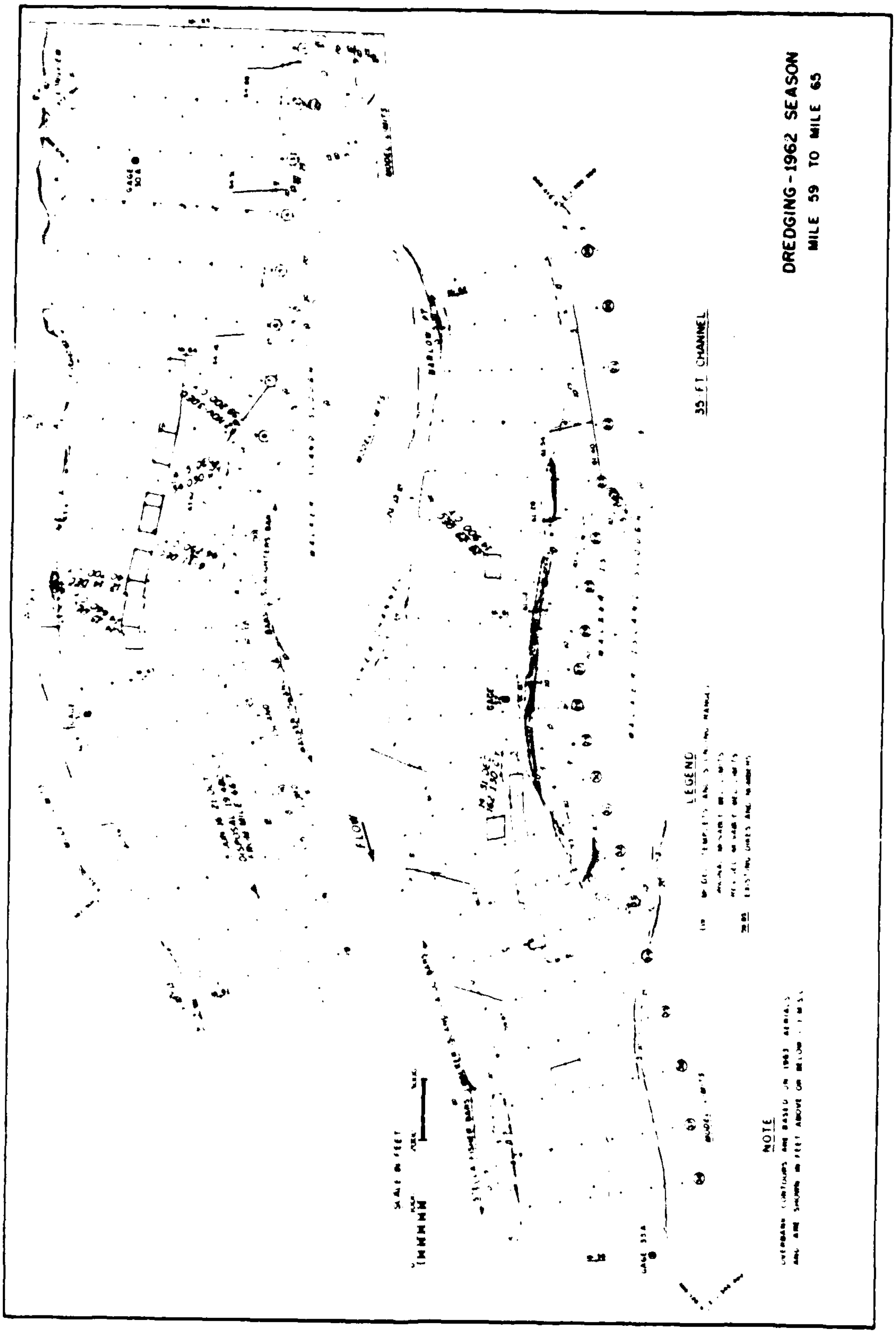

DREDGING-1962 SEASON
MILE 59 TO MILE 65
35 FT CHANNEL
LEGEND
NOTE
FLOW

PLATE 8

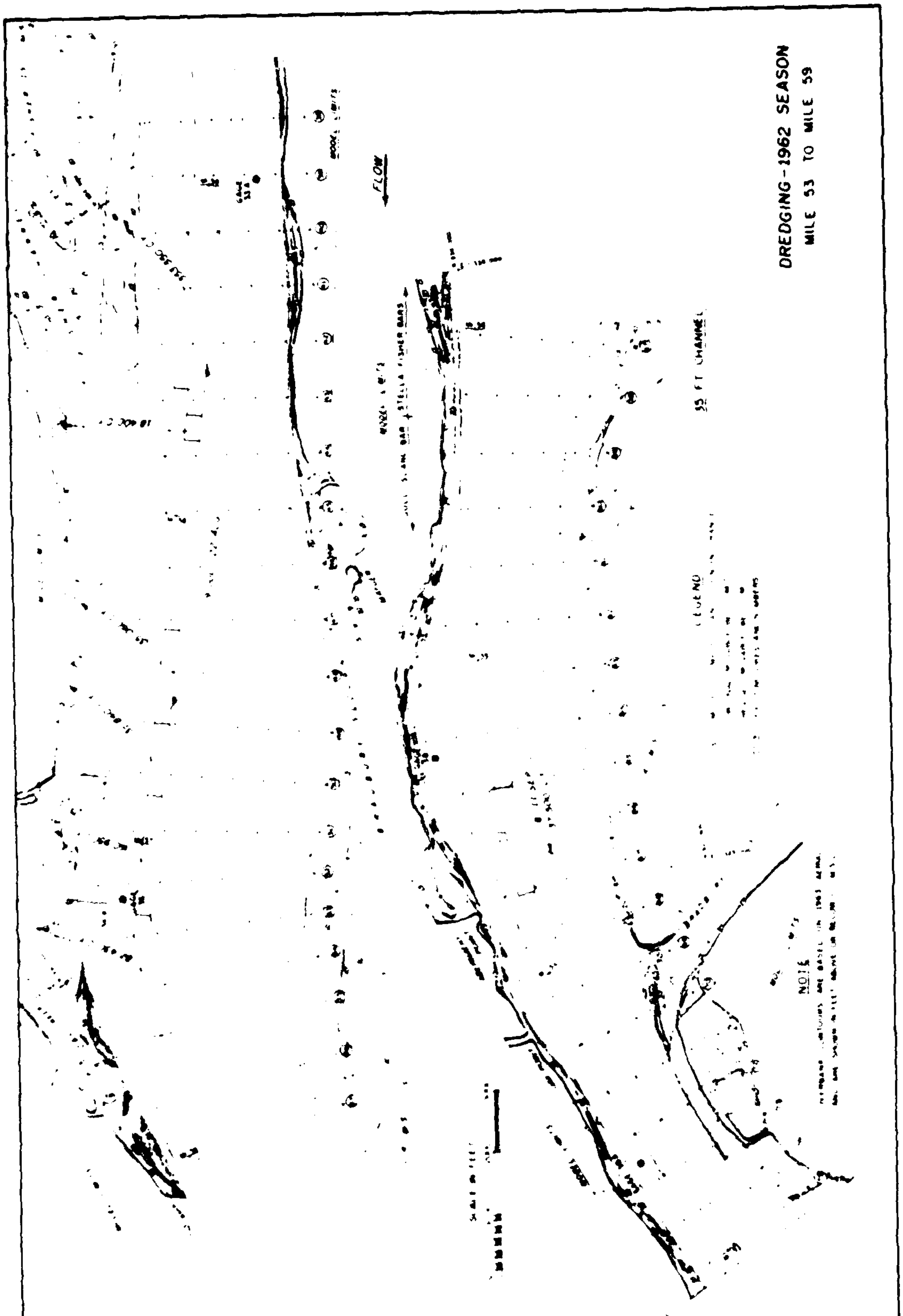

DREDGING-1962 SEASON
MILE 53 TO MILE 59
FLOW
35 FT CHANNEL
LEGEND
NOTE

PLATE 9

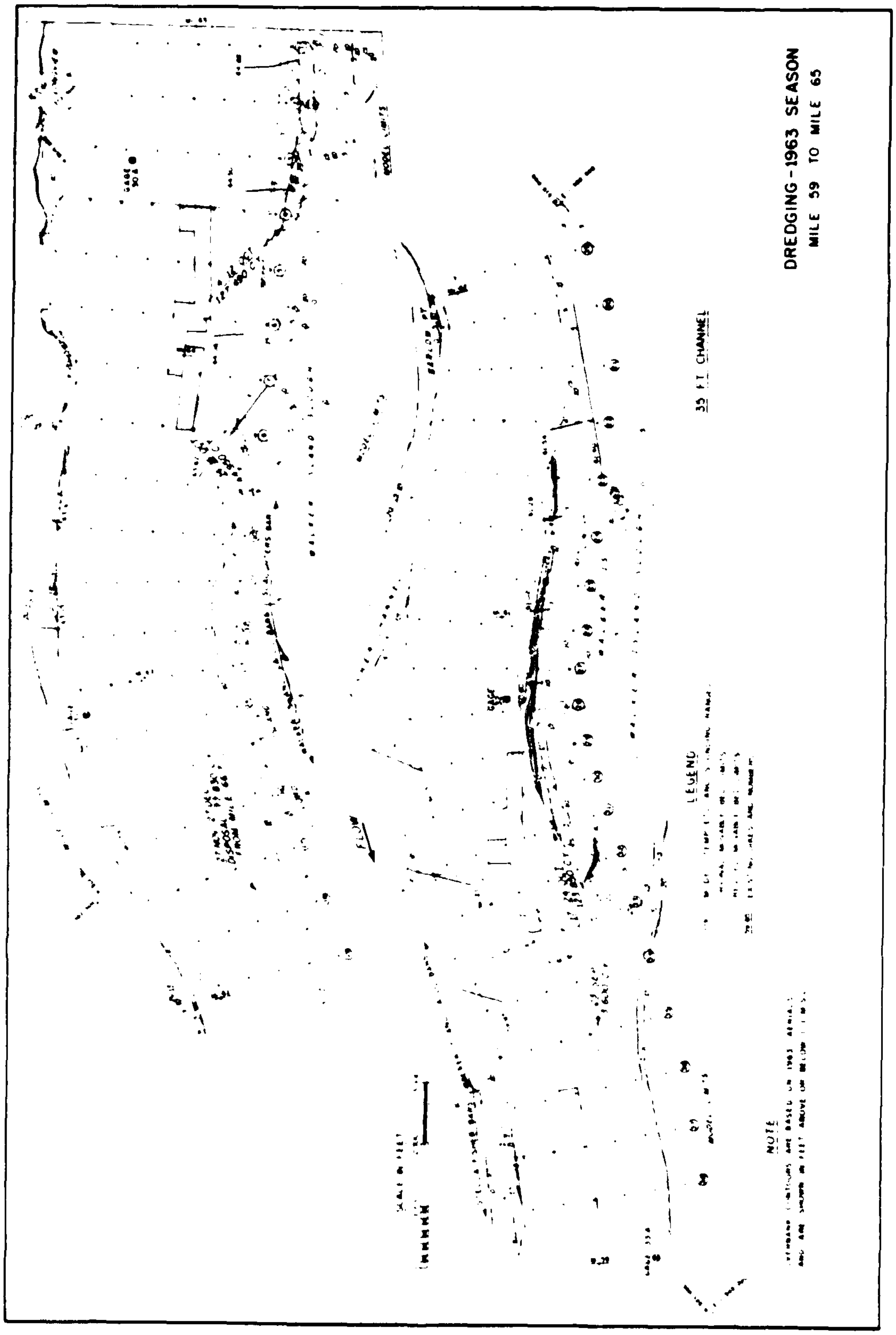

DREDGING-1963 SEASON
MILE 59 TO MILE 65
35 FT CHANNEL
LEGEND
NOTE
FLOW

PLATE 10

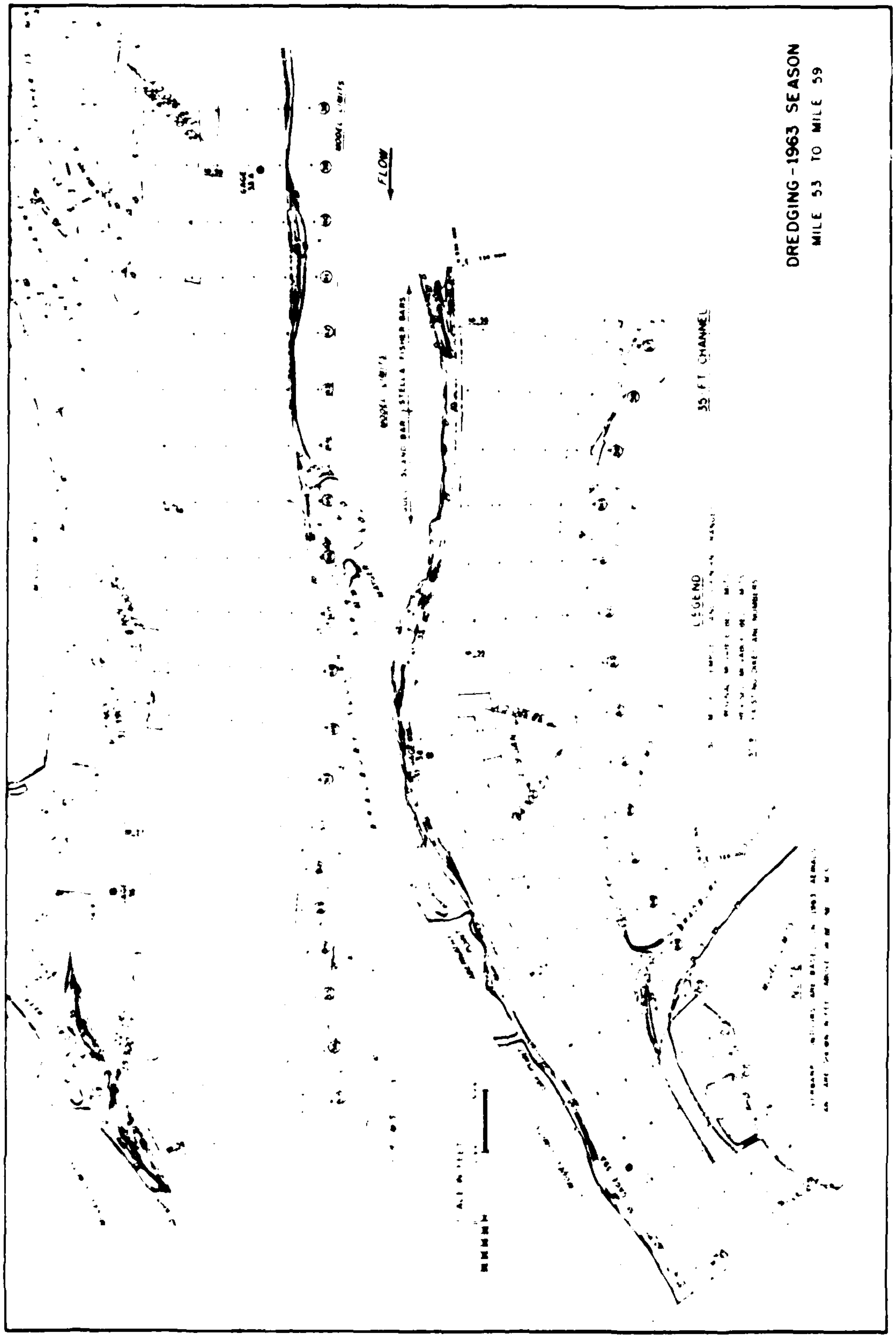
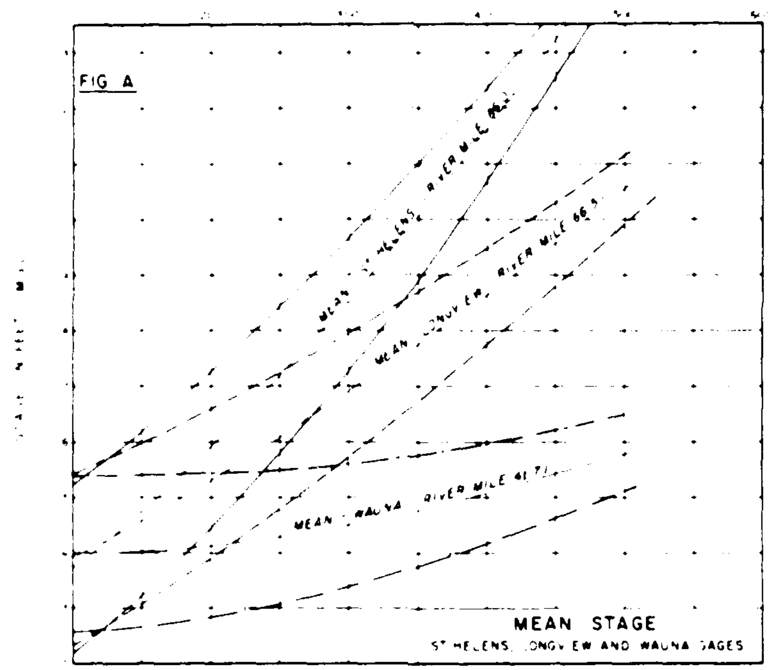
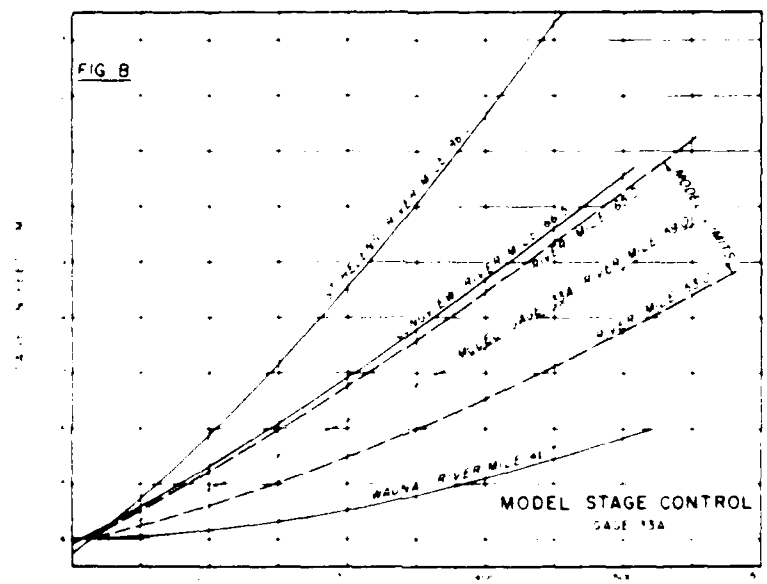

DREDGING-1963 SEASON
MILE 53 TO MILE 59
FLOW
35 FT CHANNEL
LEGEND

PLATE 11

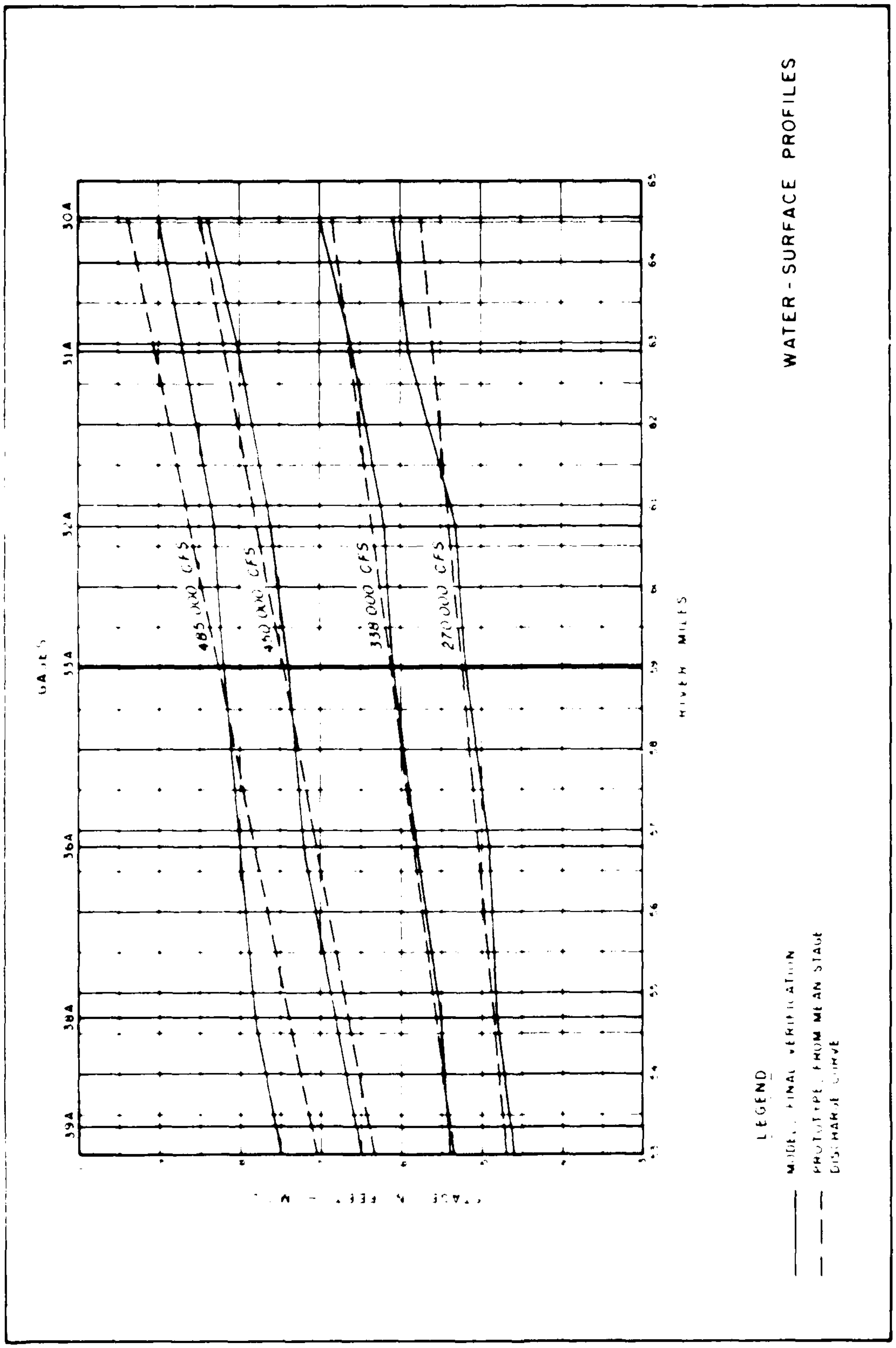




FRESH WATER DISCHARGE IN 1000 CFS

NOTE

STAGE-DISCHARGE CURVES
OCTOBER 1961 TO MARCH 1964


WATER-SURFACE PROFILES
GAGES
30A
31A
32A
33A
35A
36A
38A
39A
485,000 CFS
450,000 CFS
338,000 CFS
270,000 CFS
RIVER MILES
LEGEND
MODEL, FINAL VERIFICATION
PROTOTYPE, FROM MEAN STAGE DISCHARGE CURVE

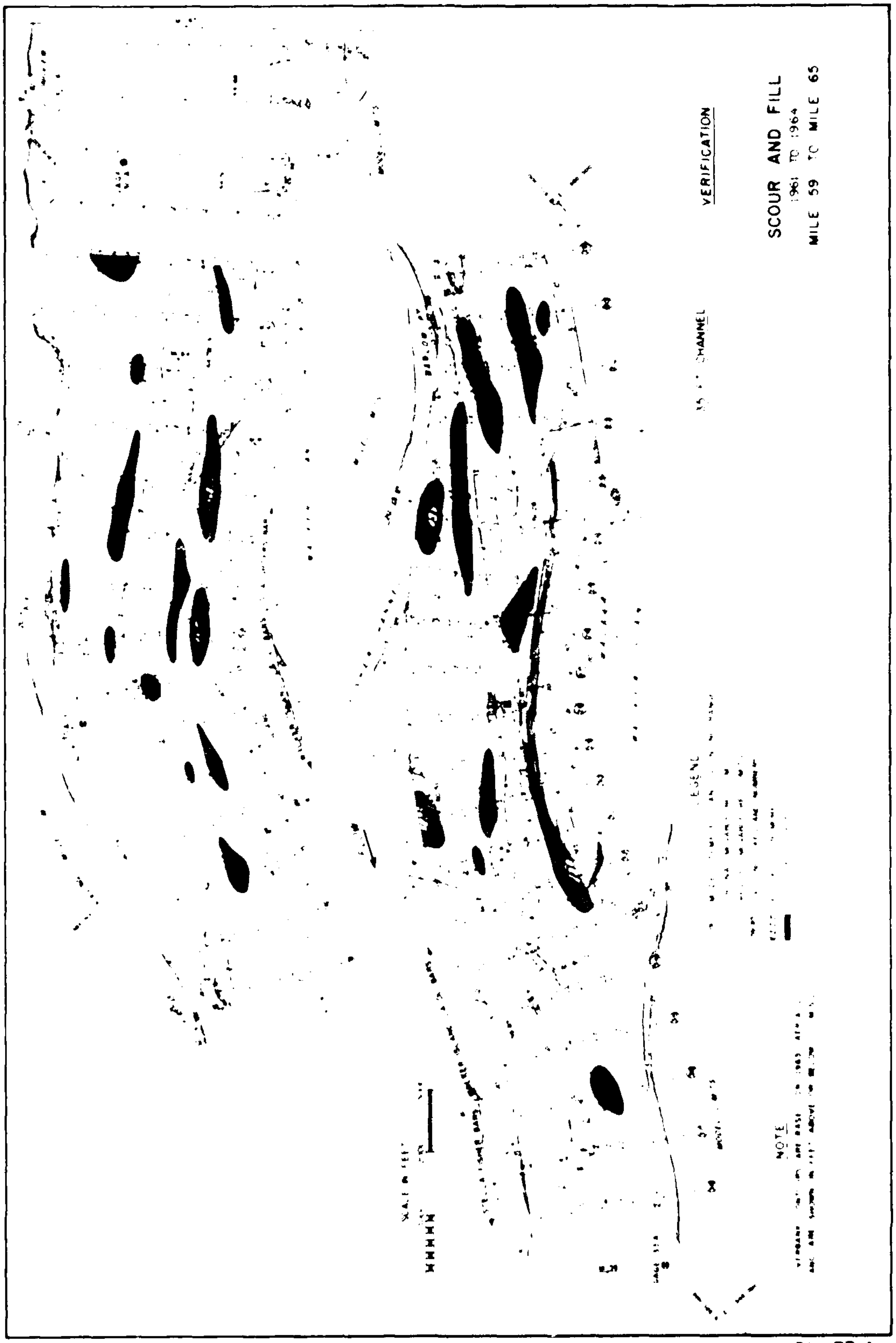

VERIFICATION
SCOUR AND FILL
1961 TO 1964
MILE 59 TO MILE 65
LEGEND
NOTE

PLATE 14

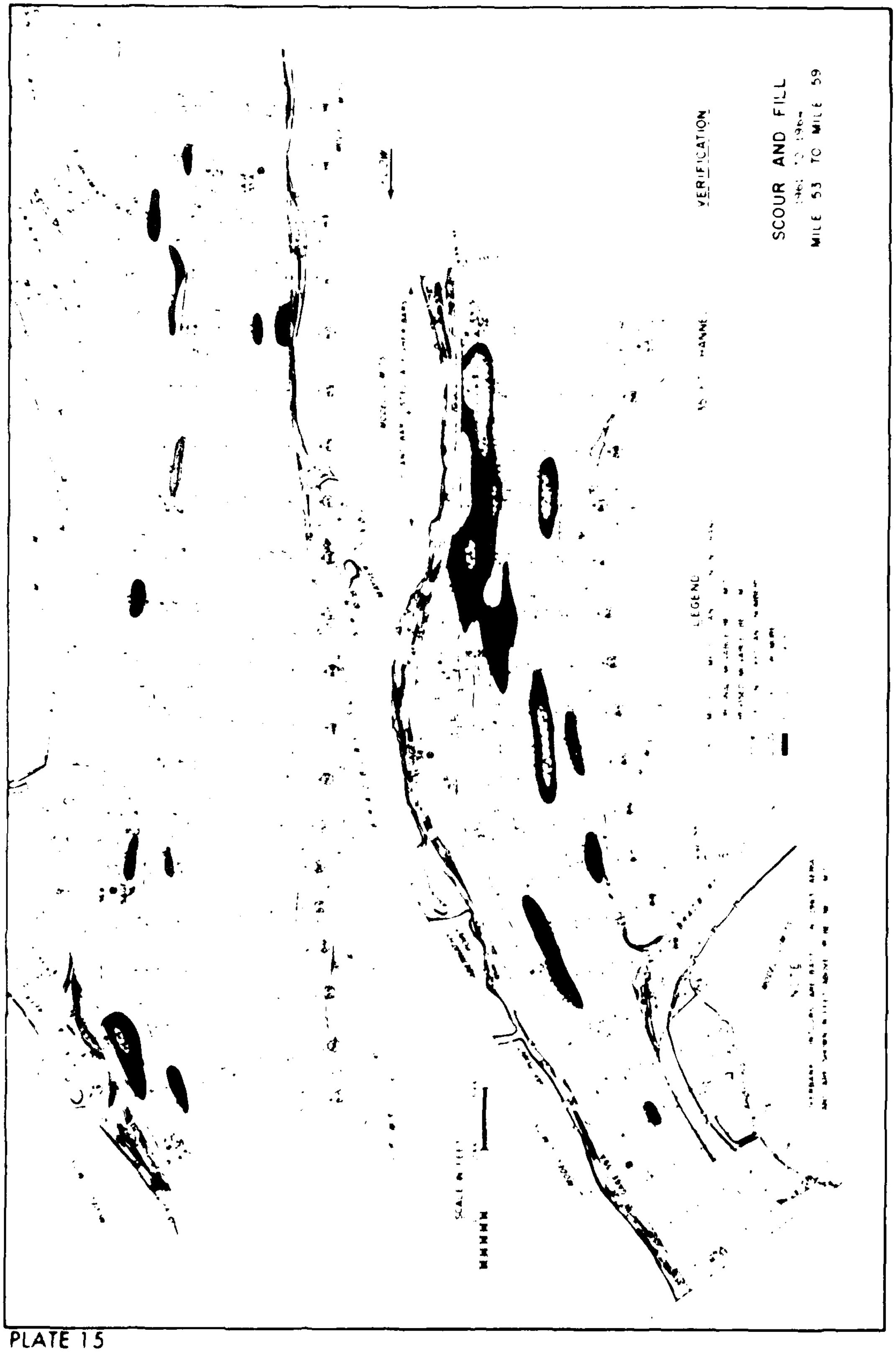


PLATE 15

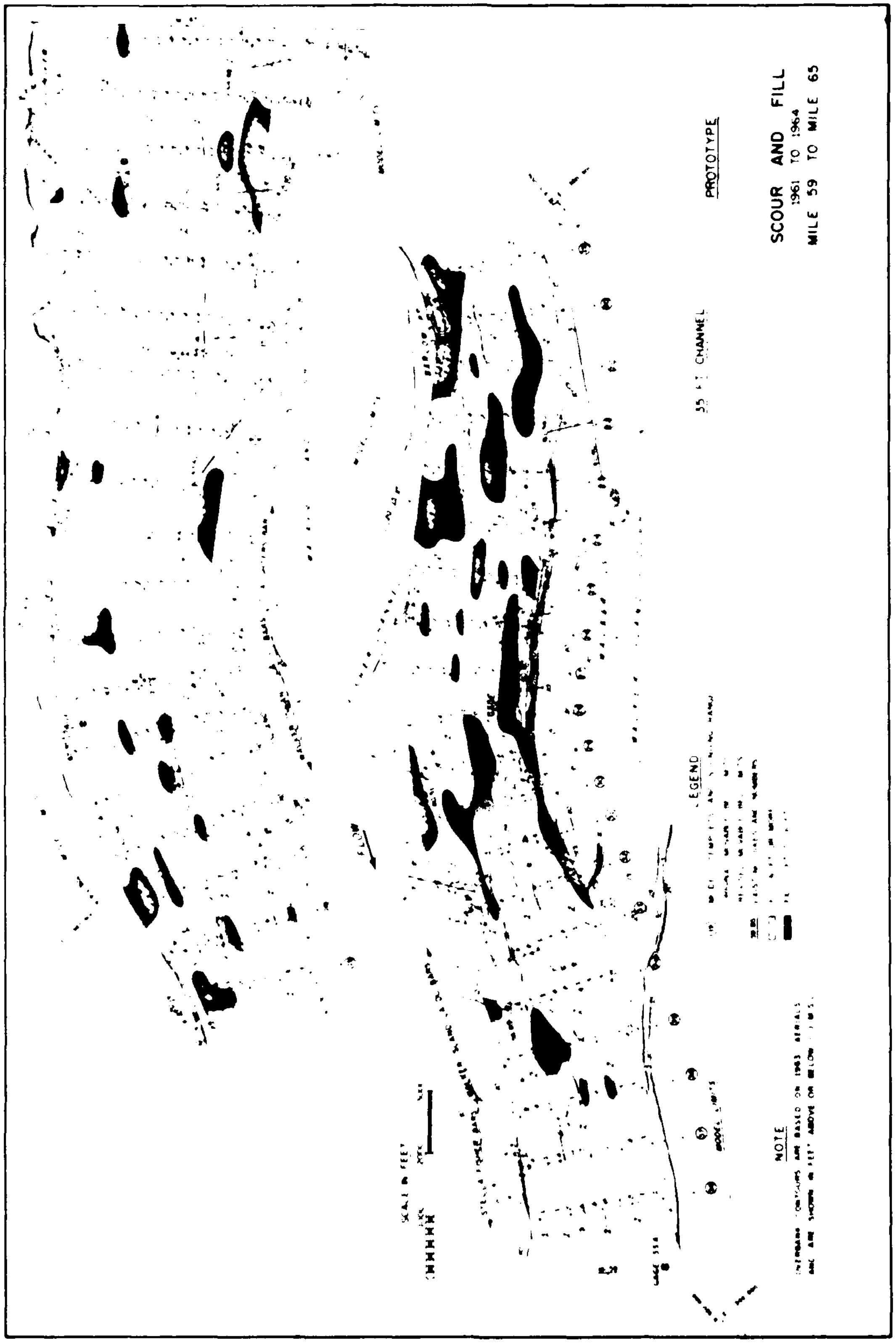

SCOUR AND FILL
1961 TO 1964
MILE 59 TO MILE 65
PROTOTYPE
55 FT CHANNEL
LEGEND
NOTE
SCALE IN FEET
FLOW

PLATE 16

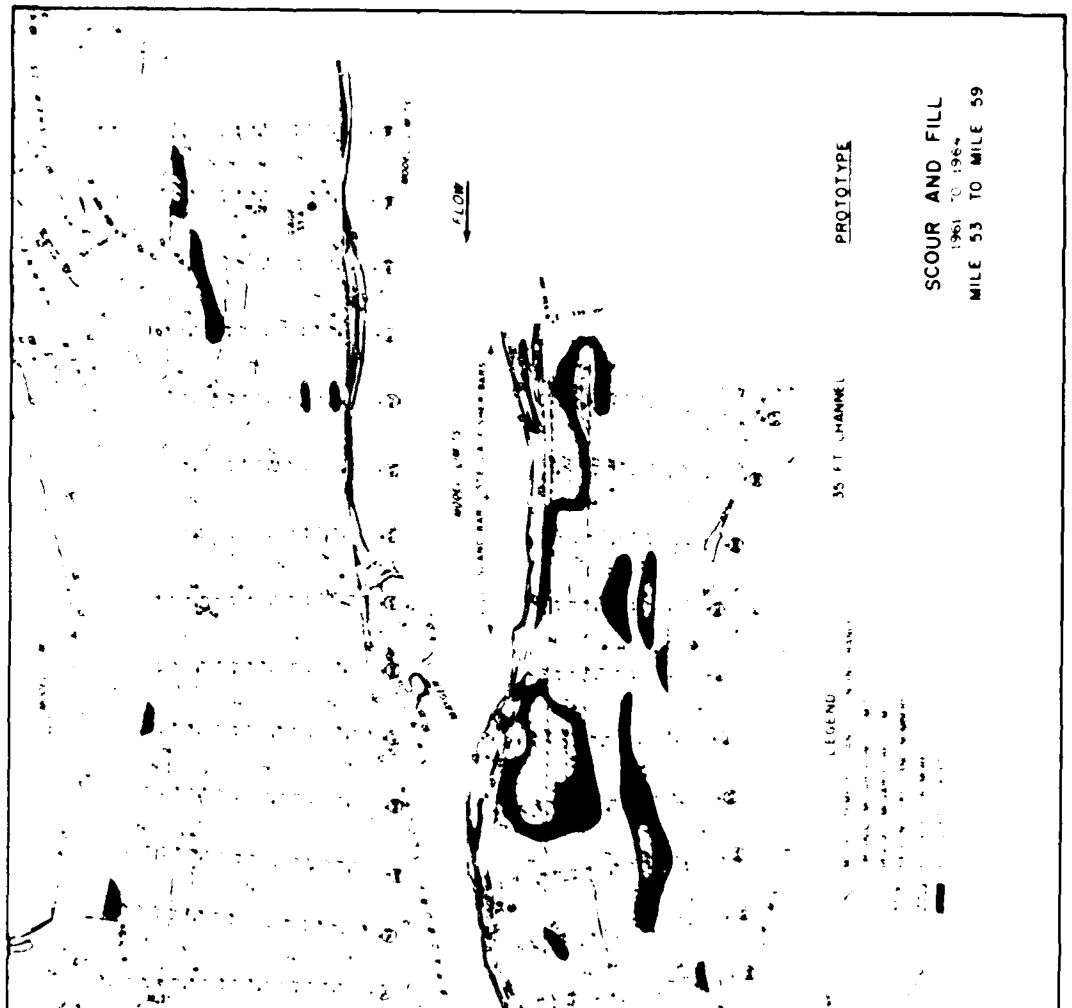
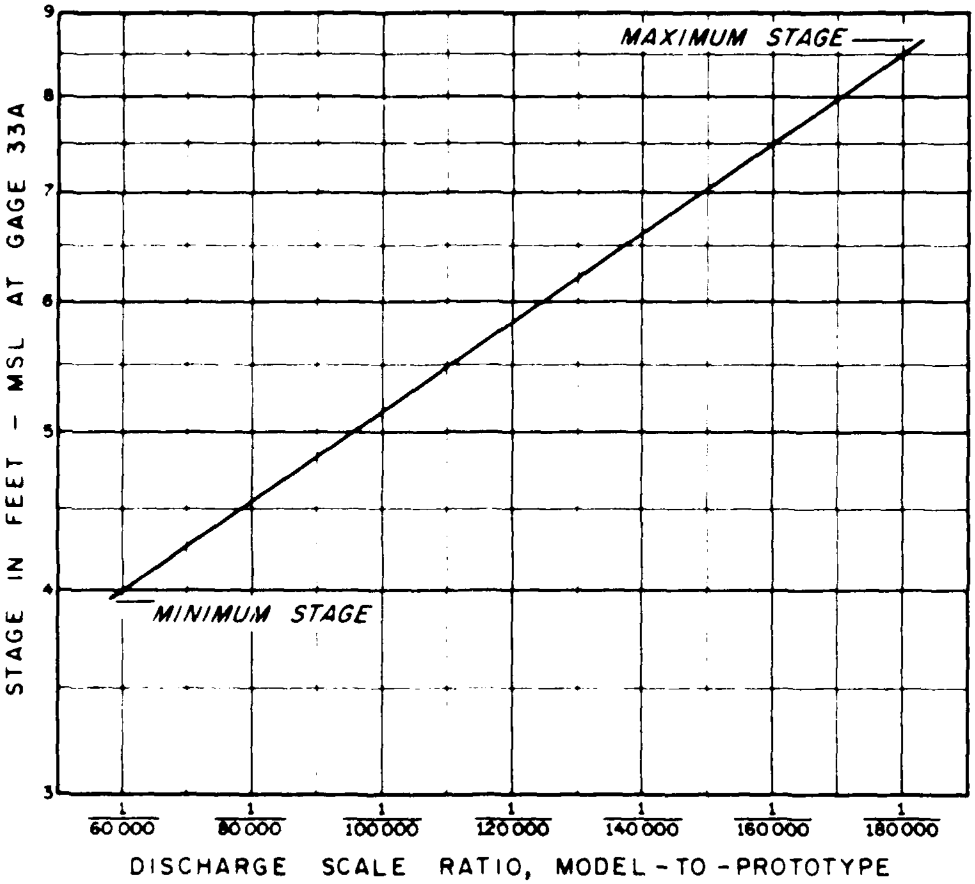
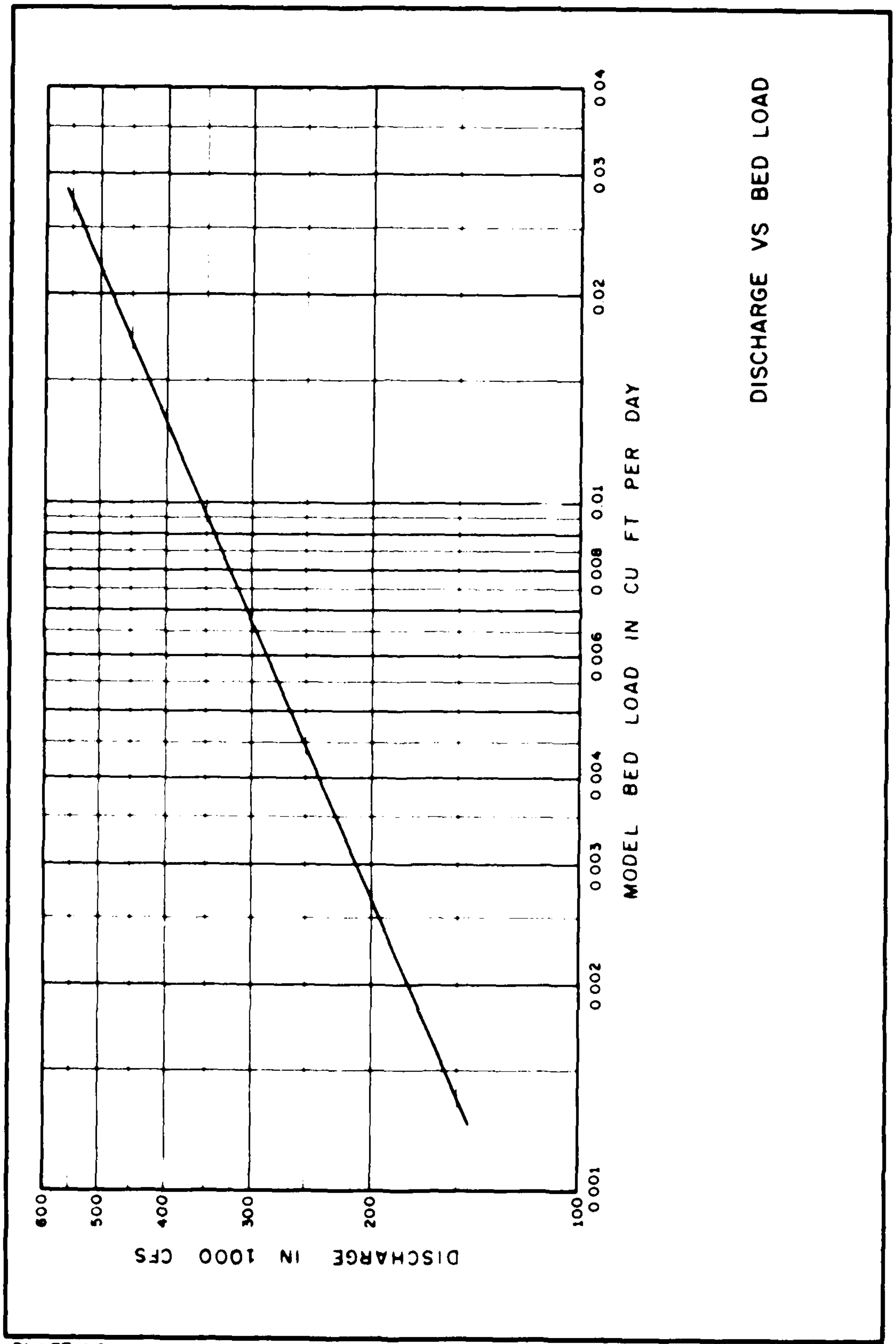

PROTOTYPE
SCOUR AND FILL
1961 TO 1964
MILE 53 TO MILE 59
FLOW
LEGEND
35 FT CHANNEL
SCALE IN FEET

PLATE 17

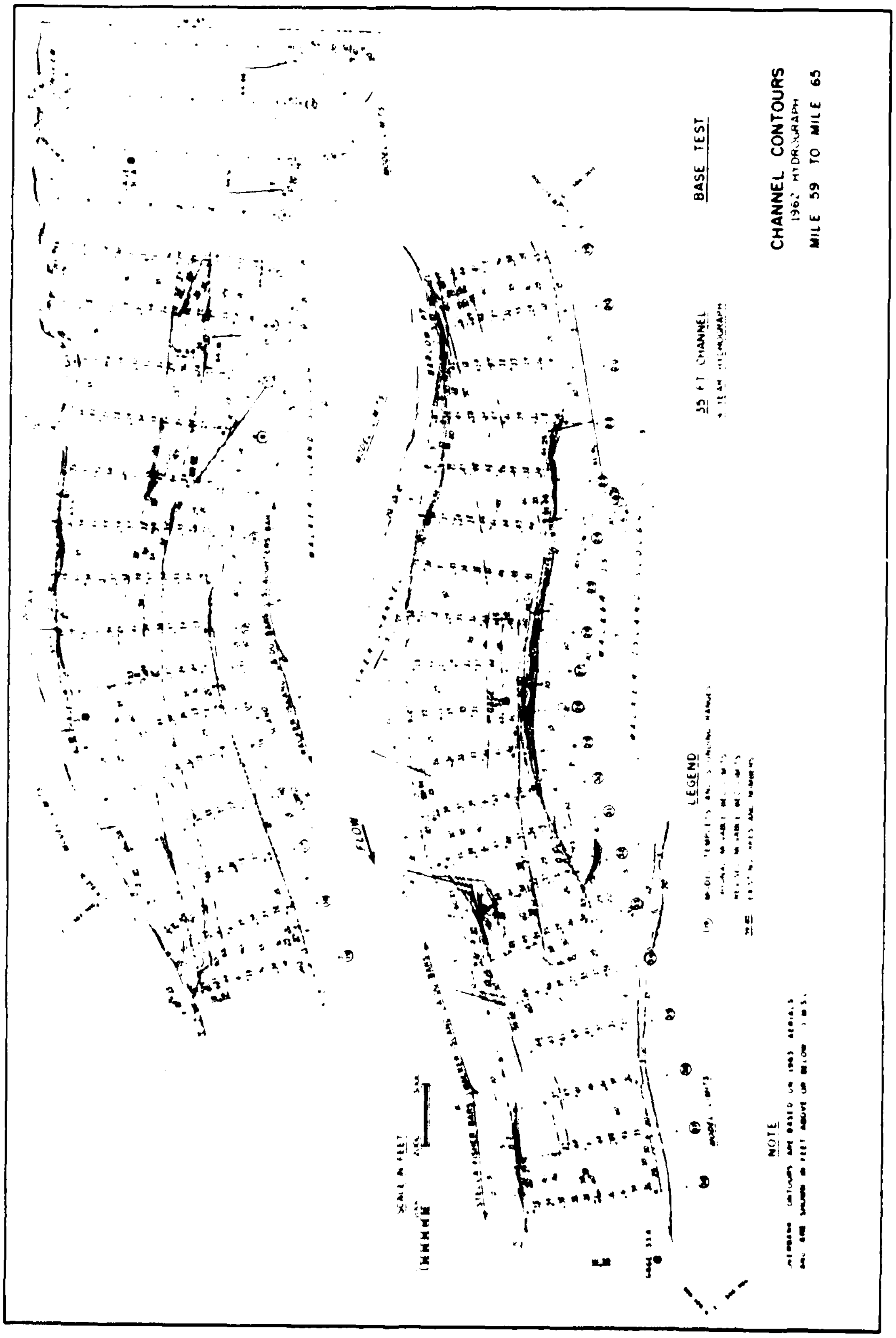


STAGE DISCHARGE RELATION



DISCHARGE VS BED LOAD

PLATE 19


CHANNEL CONTOURS
MILE 59 TO MILE 65
BASE TEST
LEGEND
NOTE
FLOW

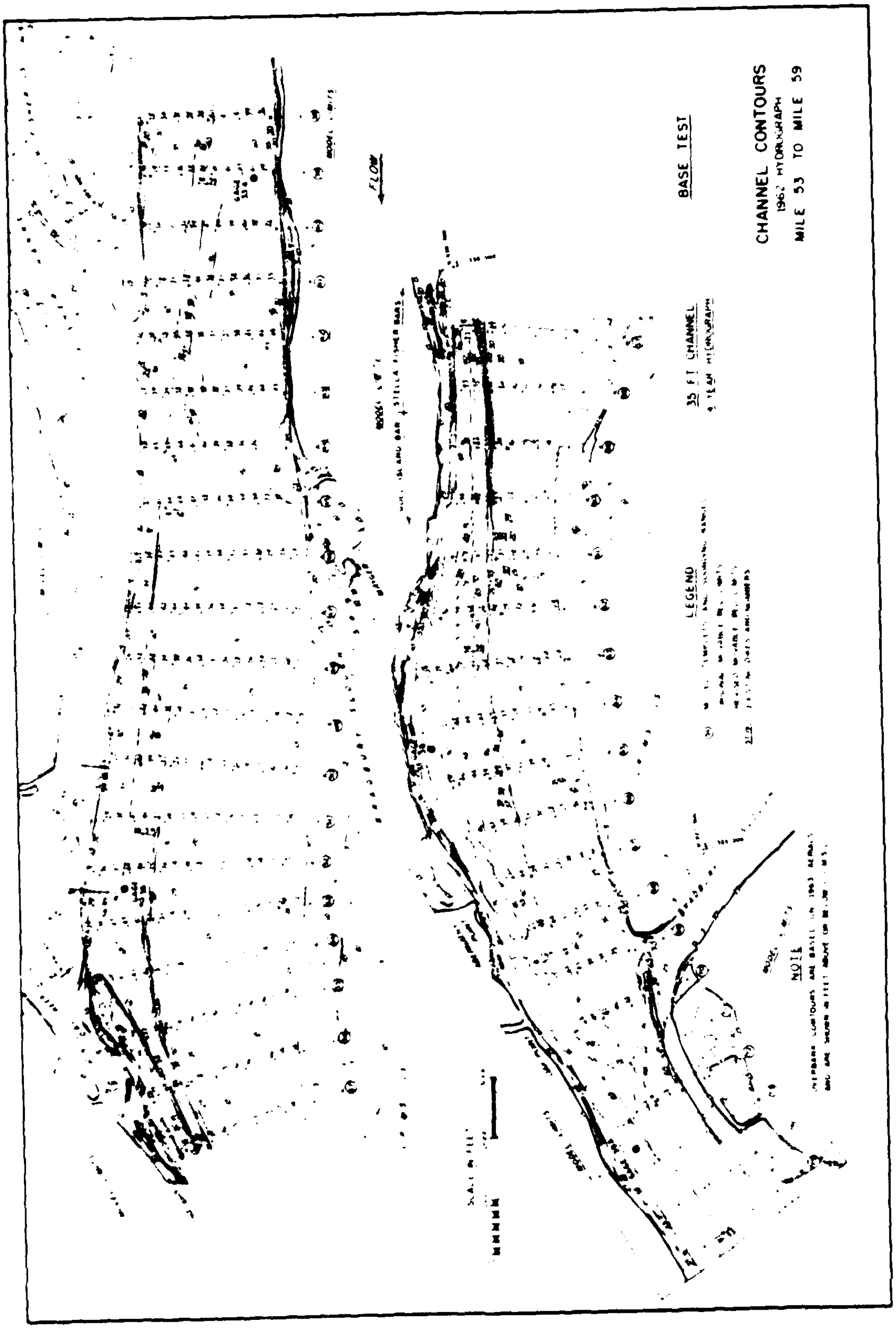

CHANNEL CONTOURS
1962 HYDROGRAPH
MILE 53 TO MILE 59
BASE TEST
FLOW
35 FT CHANNEL
LEGEND
NOTE

PLATE 21

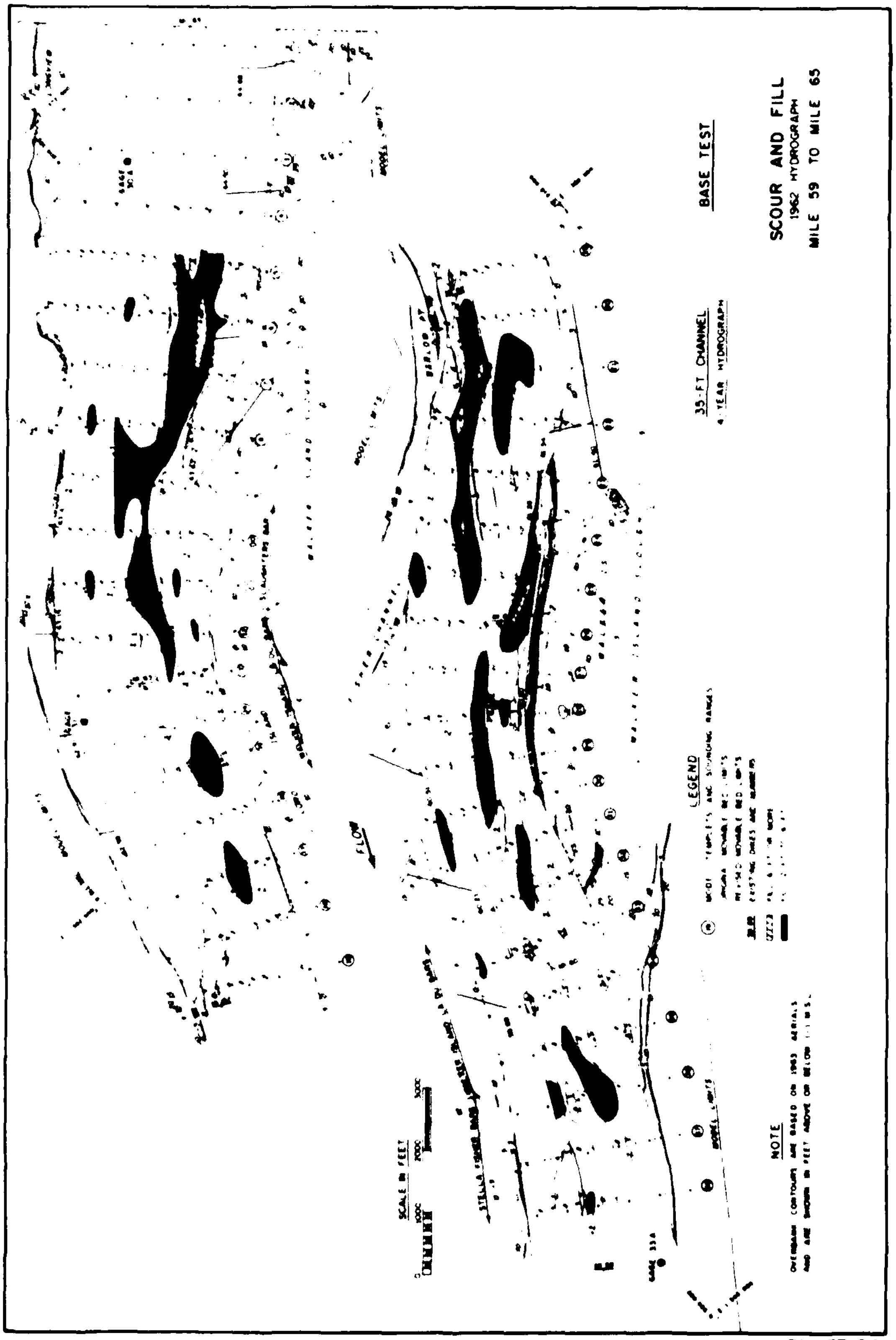

BASE TEST
SCOUR AND FILL
1962 HYDROGRAPH
MILE 59 TO MILE 65
35-FT CHANNEL
4-YEAR HYDROGRAPH
LEGEND
NOTE
SCALE IN FEET
FLOW

PLATE 22

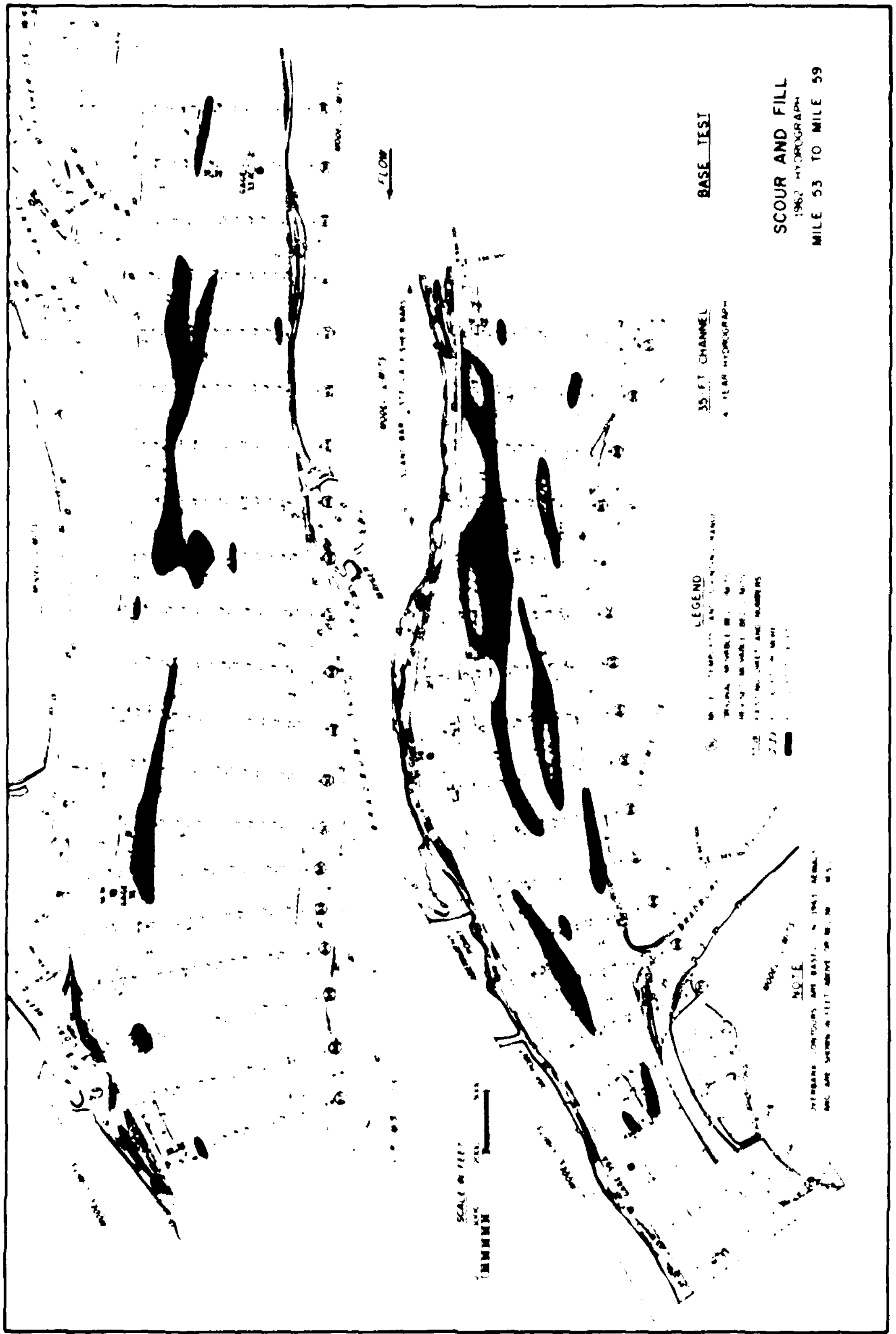
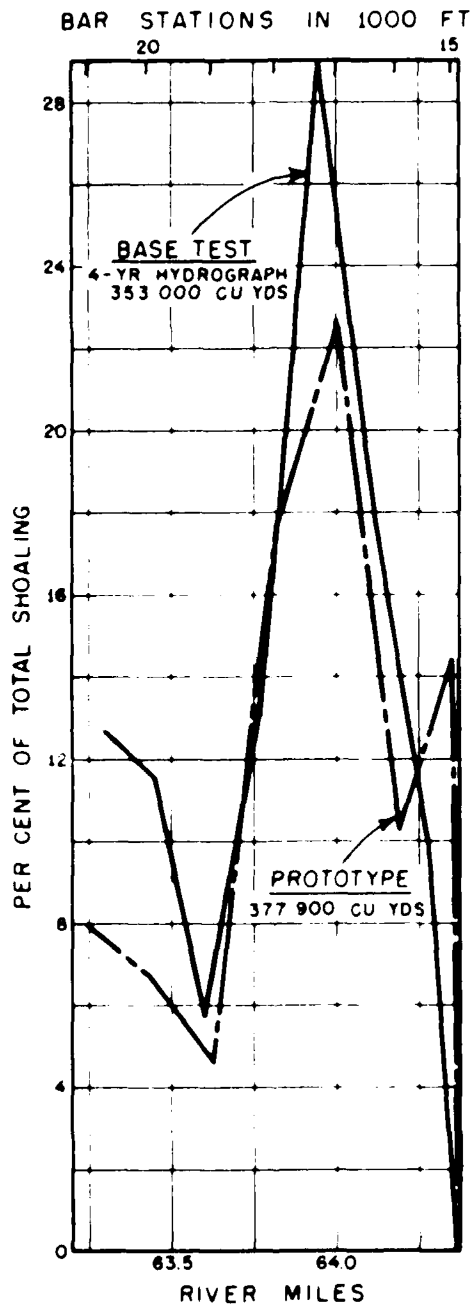

SCOUR AND FILL
1962 HYDROGRAPH
MILE 53 TO MILE 59
BASE TEST
35 FT CHANNEL
FLOW
LEGEND
NOTE
SCALE IN FEET

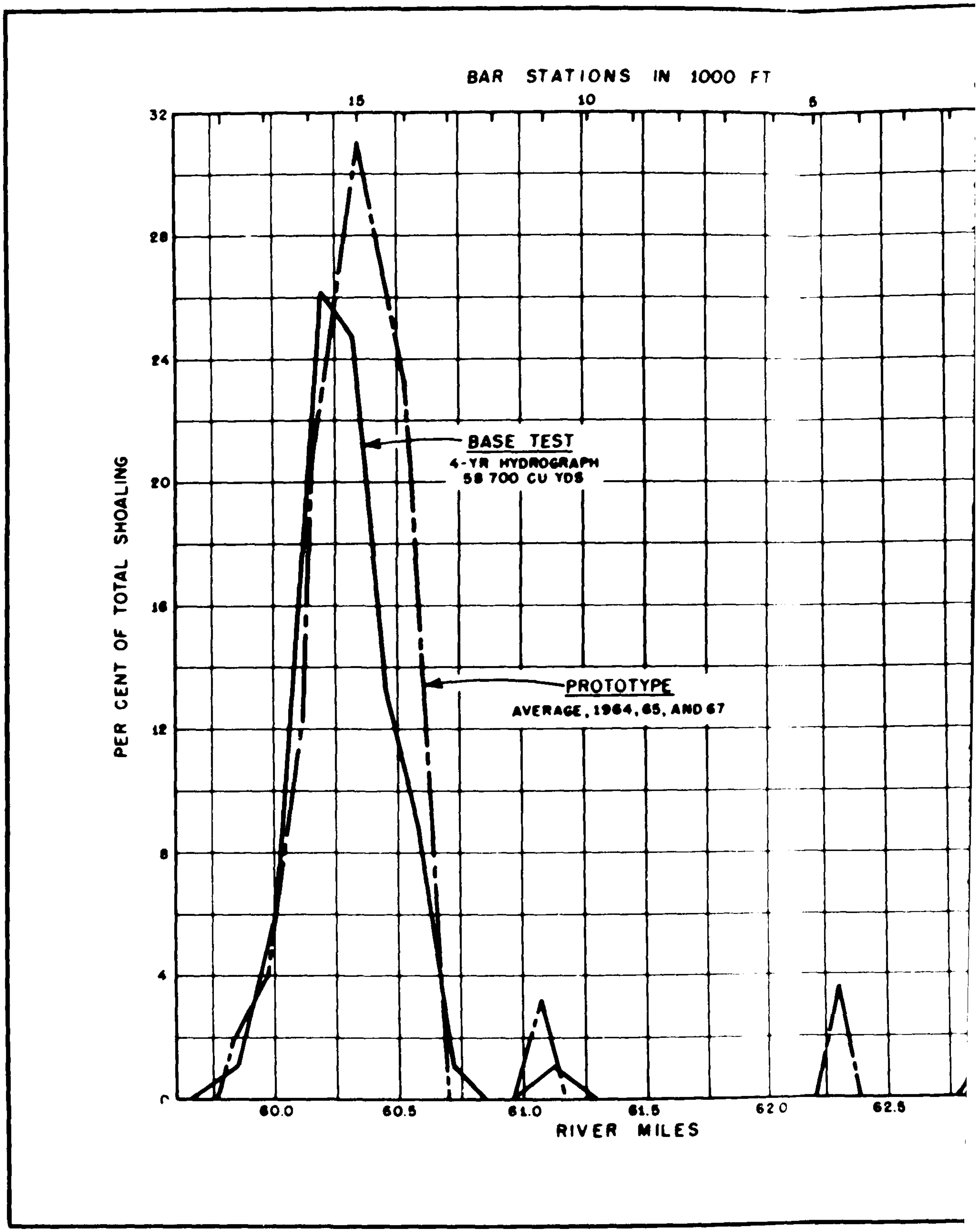
PLATE 23



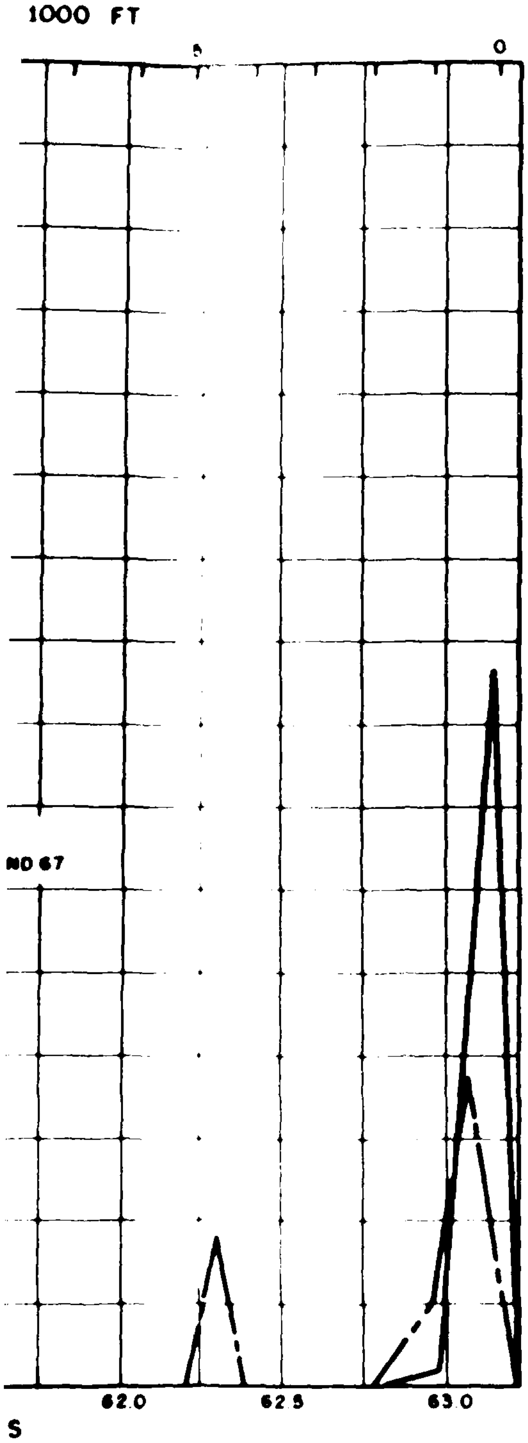
35-FT CHANNEL

SHOALING DISTRIBUTION
SLAUGHTERS BAR

PLATE 24



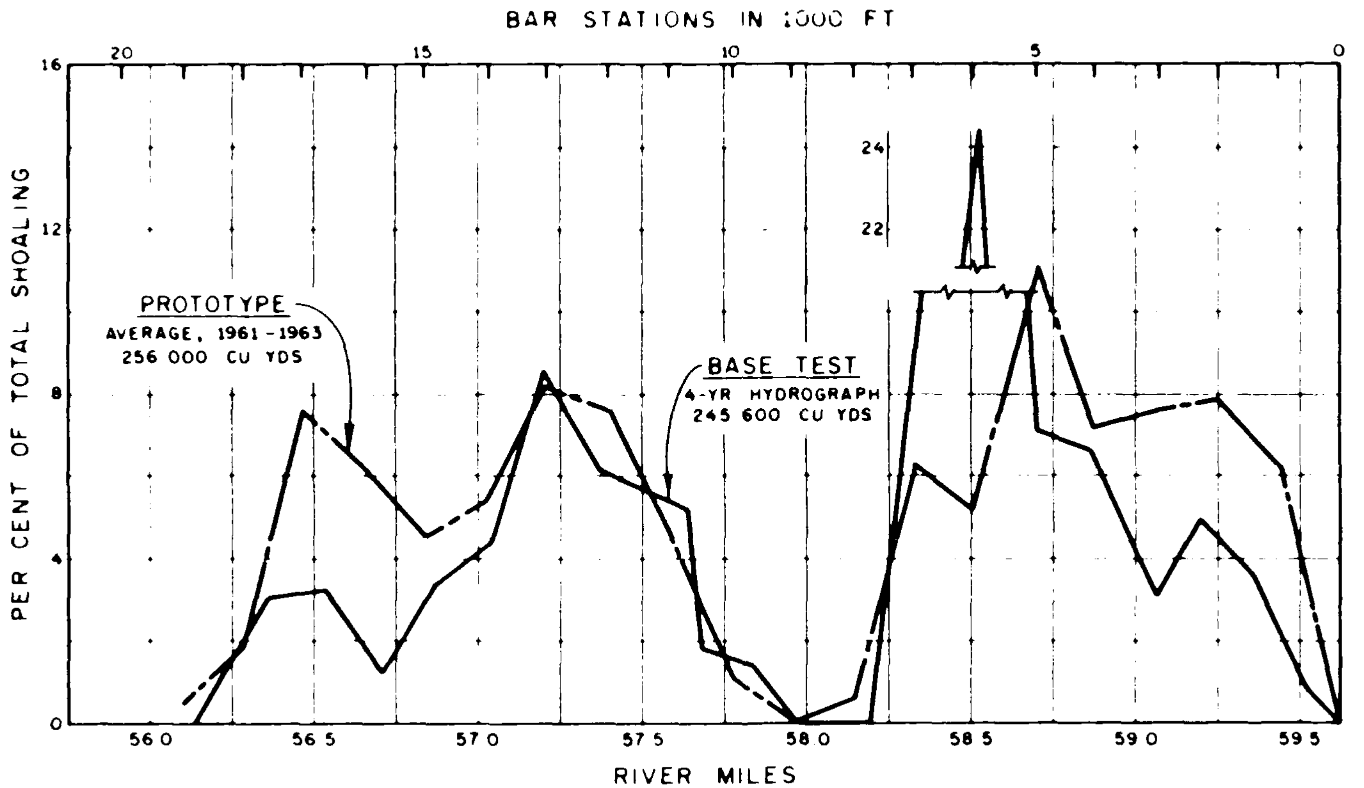
BAR STATIONS IN 1000 FT
15
10
5
32
28
24
20
16
12
8
4
0
PER CENT OF TOTAL SHOALING
BASE TEST
4-YR HYDROGRAPH
58 700 CU YDS
PROTOTYPE
AVERAGE, 1964, 65, AND 67
60.0
60.5
61.0
61.5
62.0
62.5
RIVER MILES



35-FT CHANNEL

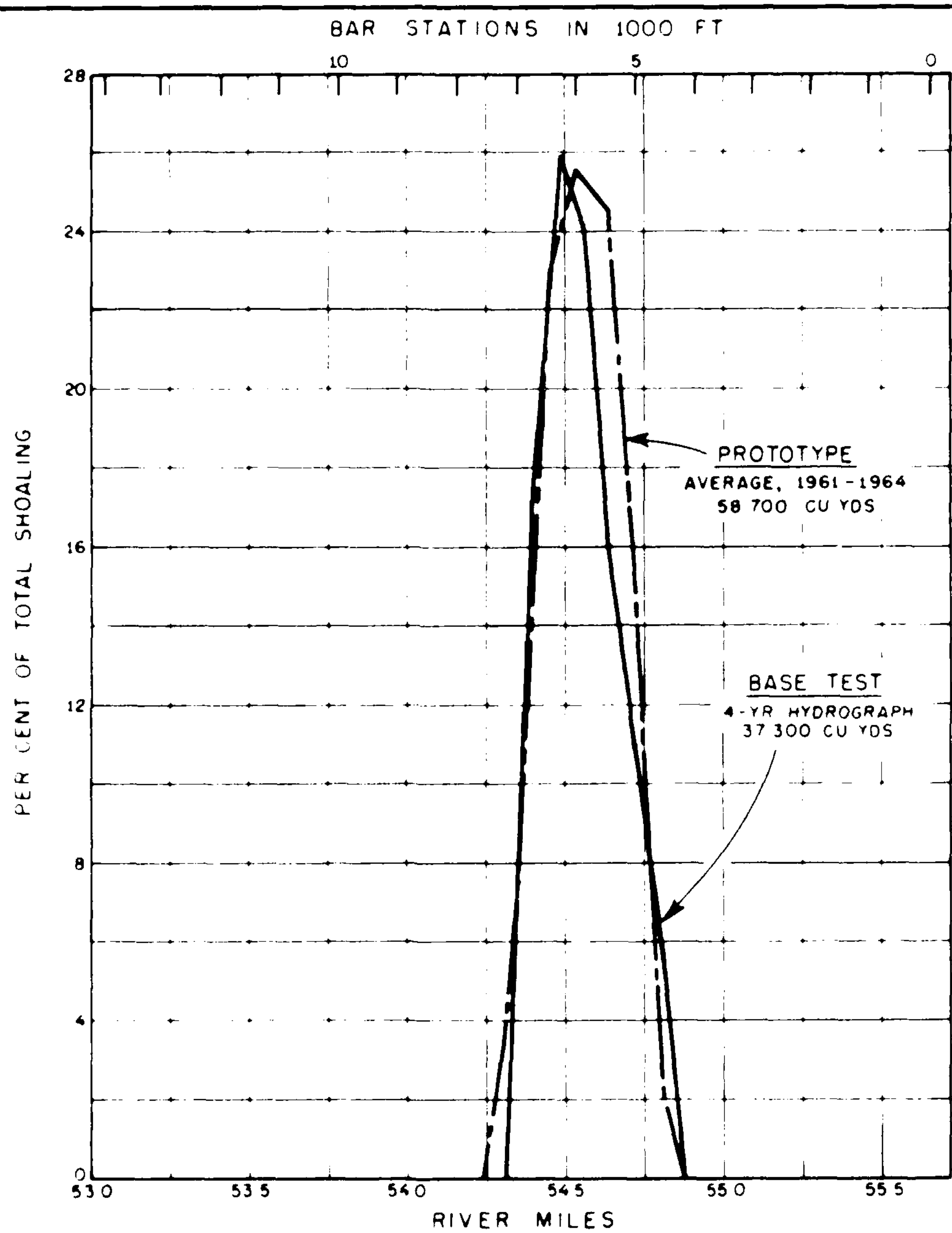
SHOALING DISTRIBUTION
WALKER ISLAND - LA DU BARS

PLATE 25



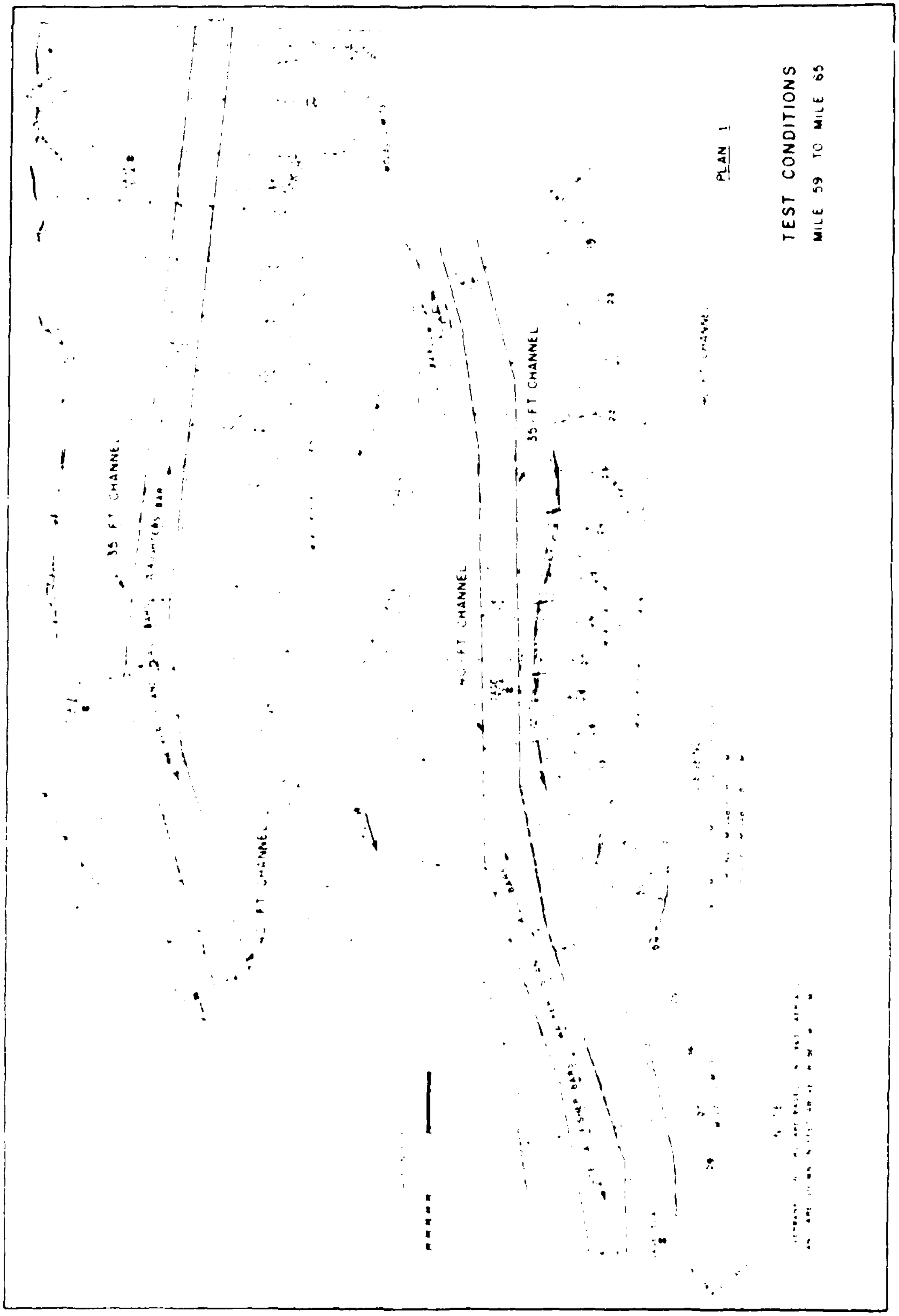
SHOALING DISTRIBUTION
STELLA-FISHER BARS

35-FT CHANNEL

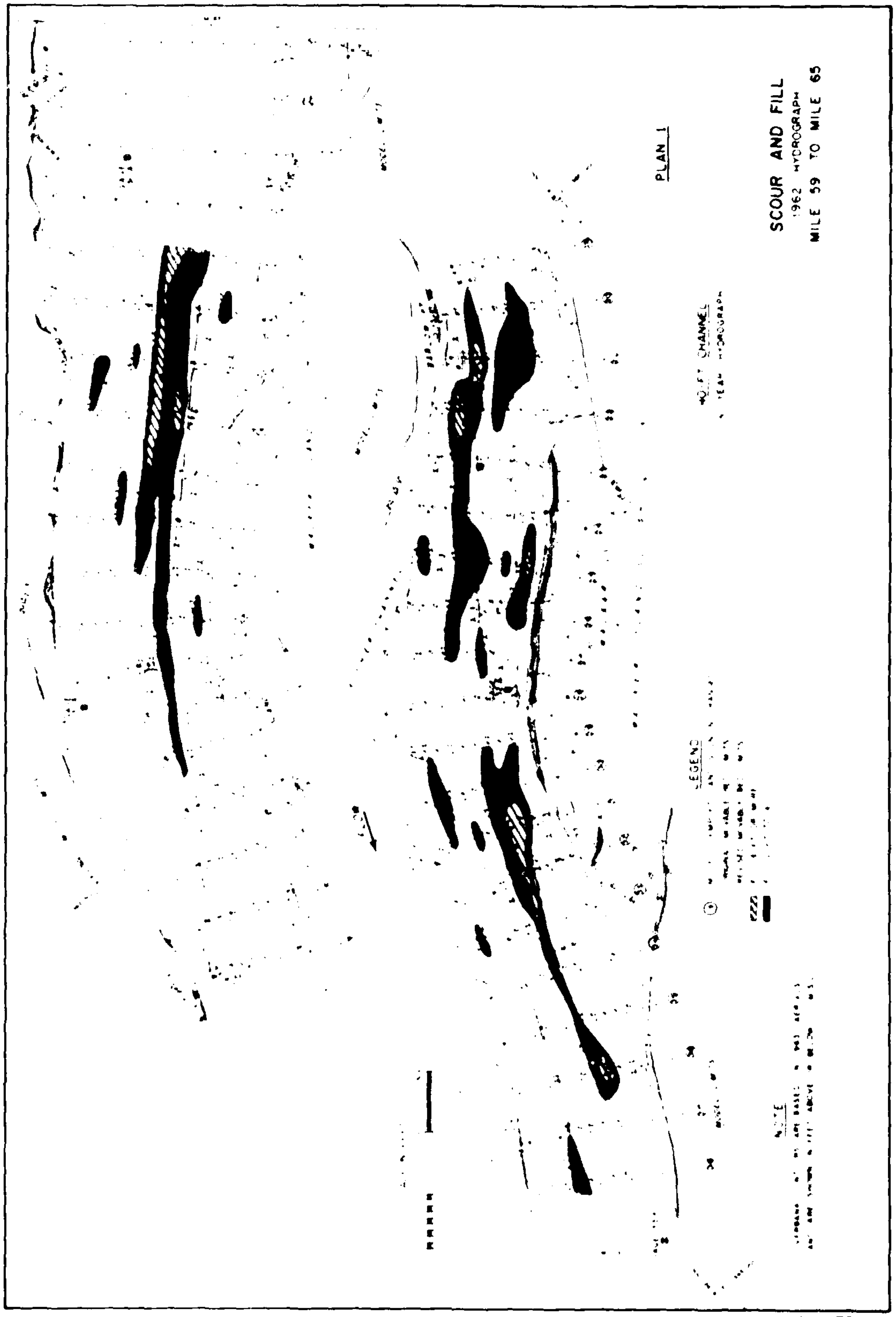


35-FT CHANNEL

SHOALING DISTRIBUTION
GULL ISLAND BAR


TEST CONDITIONS
MILE 59 TO MILE 65
PLAN 1
35 FT CHANNEL
35 FT CHANNEL
40 FT CHANNEL


TEST CONDITIONS
MILE 53 TO MILE 59
PLAN 1
40-FT CHANNEL
35-FT CHANNEL


SCOUR AND FILL
1962 HYDROGRAPH
MILE 59 TO MILE 65
PLAN 1
LEGEND
NOTE

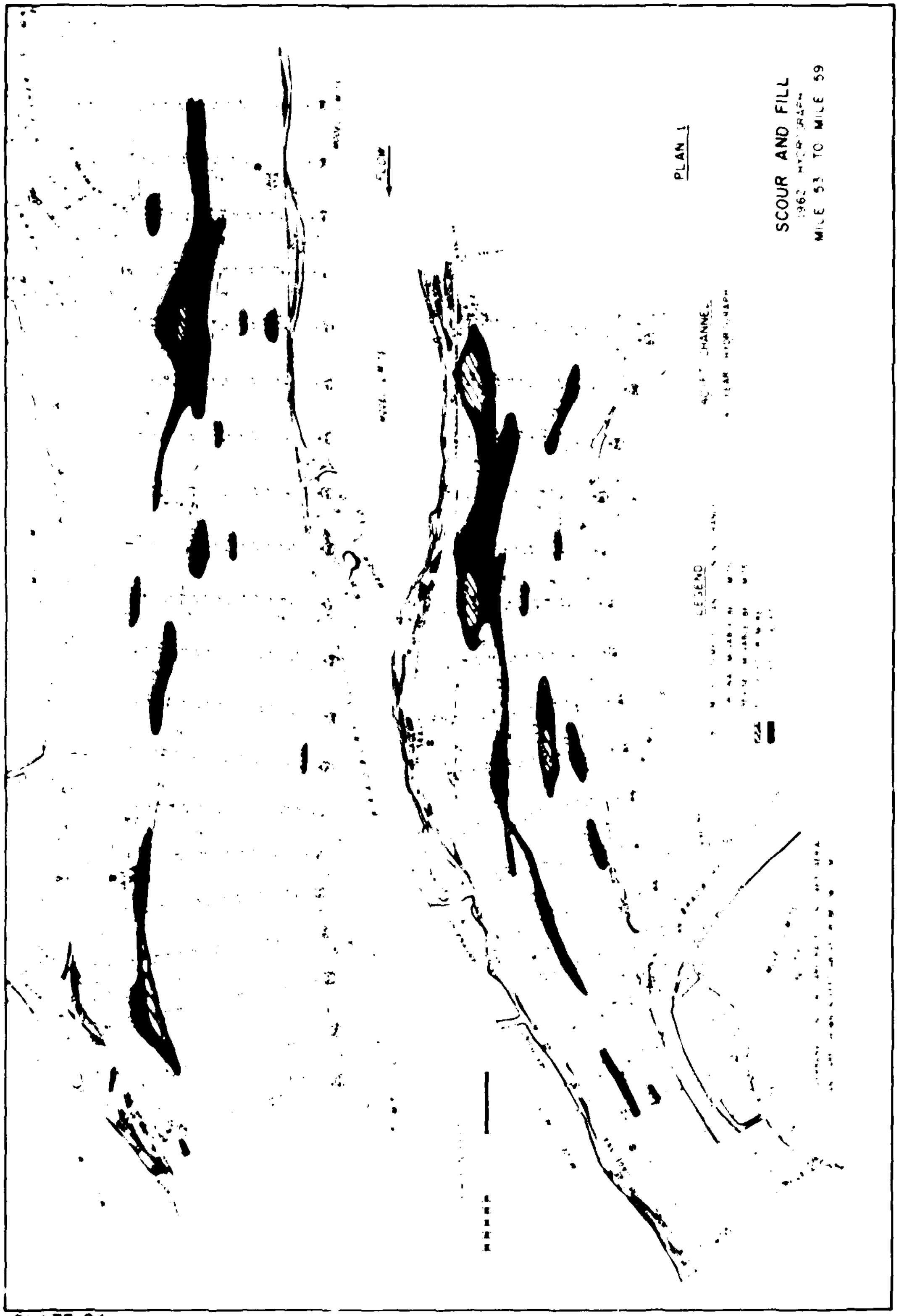
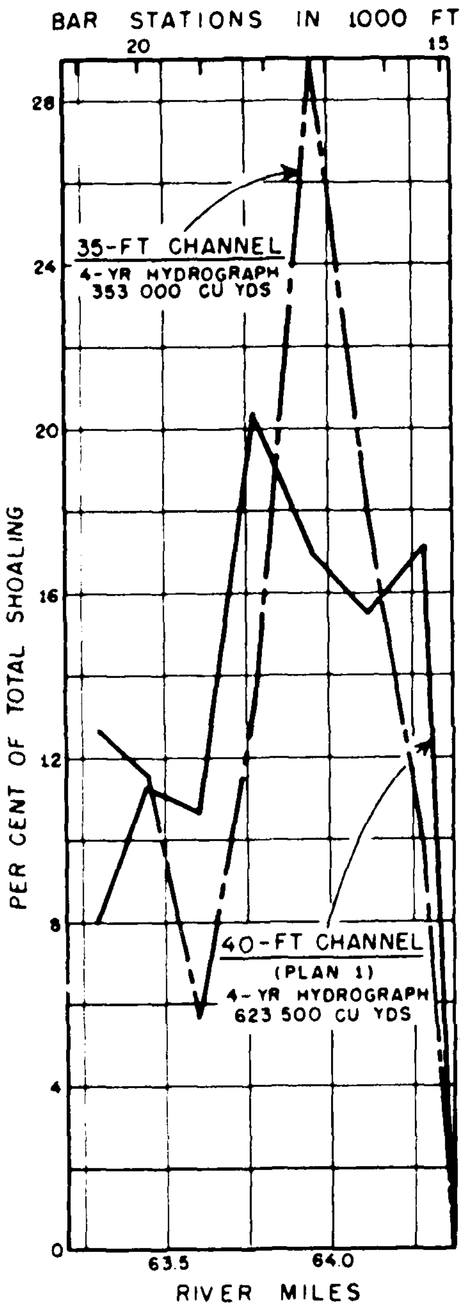
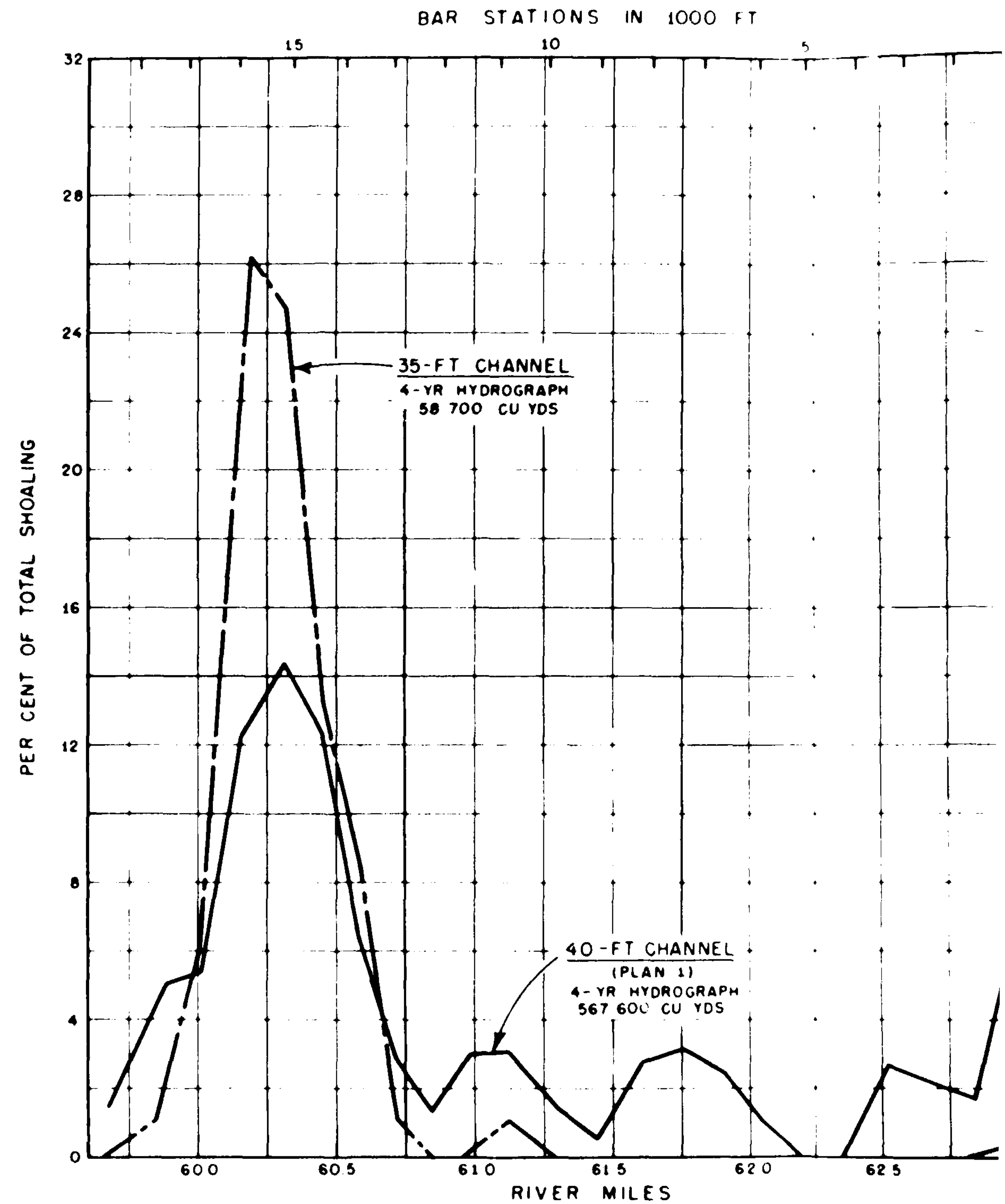


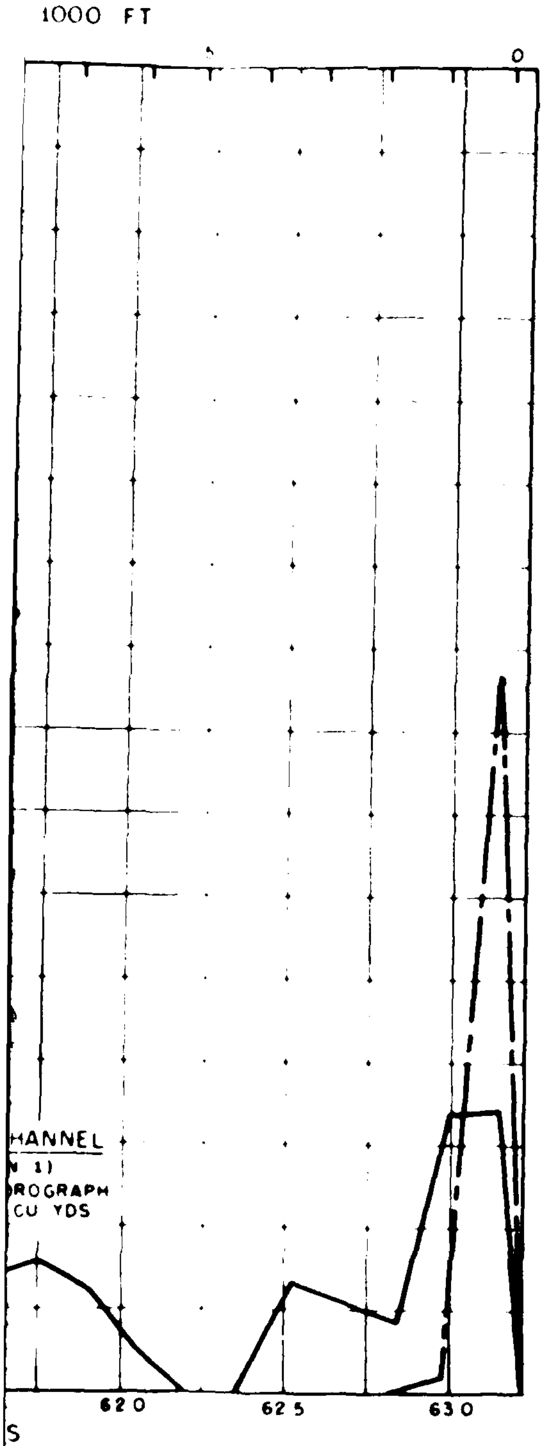
PLATE 31



35-AND 40-FT CHANNELS

SHOALING DISTRIBUTION
SLAUGHTERS BAR
BASE TESTS

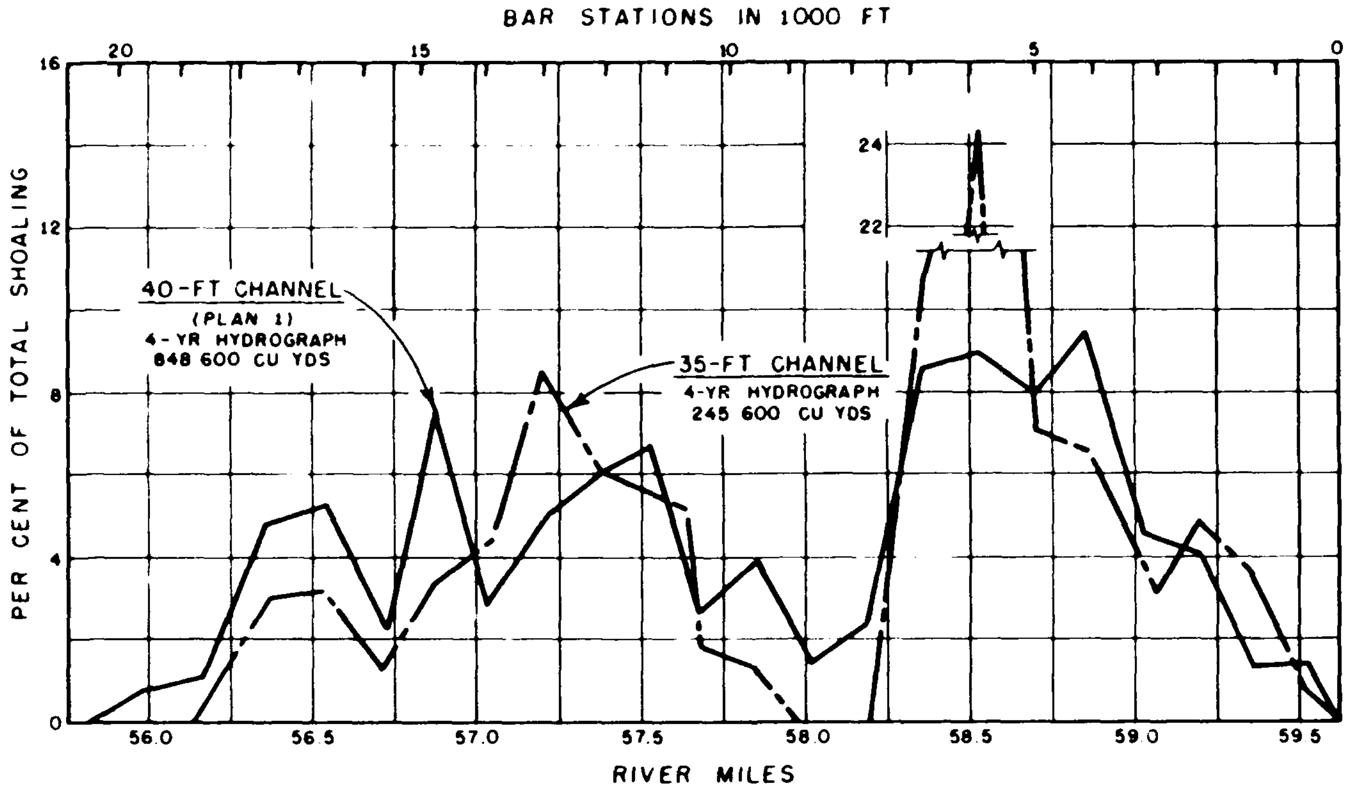

BAR STATIONS IN 1000 FT
15
10
5
32
28
24
20
16
12
8
4
0
PER CENT OF TOTAL SHOALING
35-FT CHANNEL
4-YR HYDROGRAPH
58 700 CU YDS
40-FT CHANNEL
(PLAN 1)
4-YR HYDROGRAPH
567 600 CU YDS
600
60.5
61.0
61.5
62.0
62.5
RIVER MILES



35 AND 40-FT CHANNELS

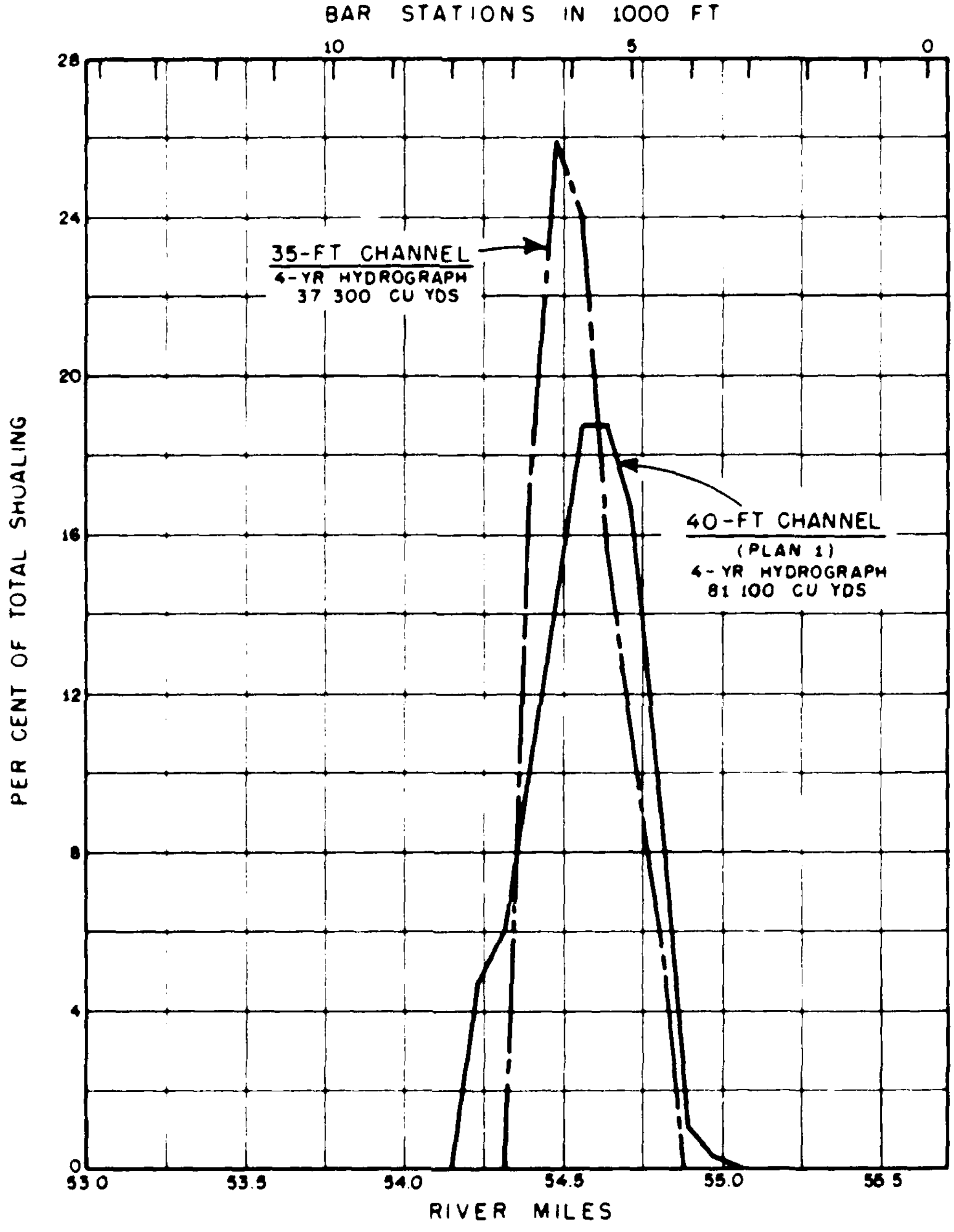
SHOALING DISTRIBUTION
WALKER ISLAND - LA DU BARS
BASE TESTS

PLATE 33



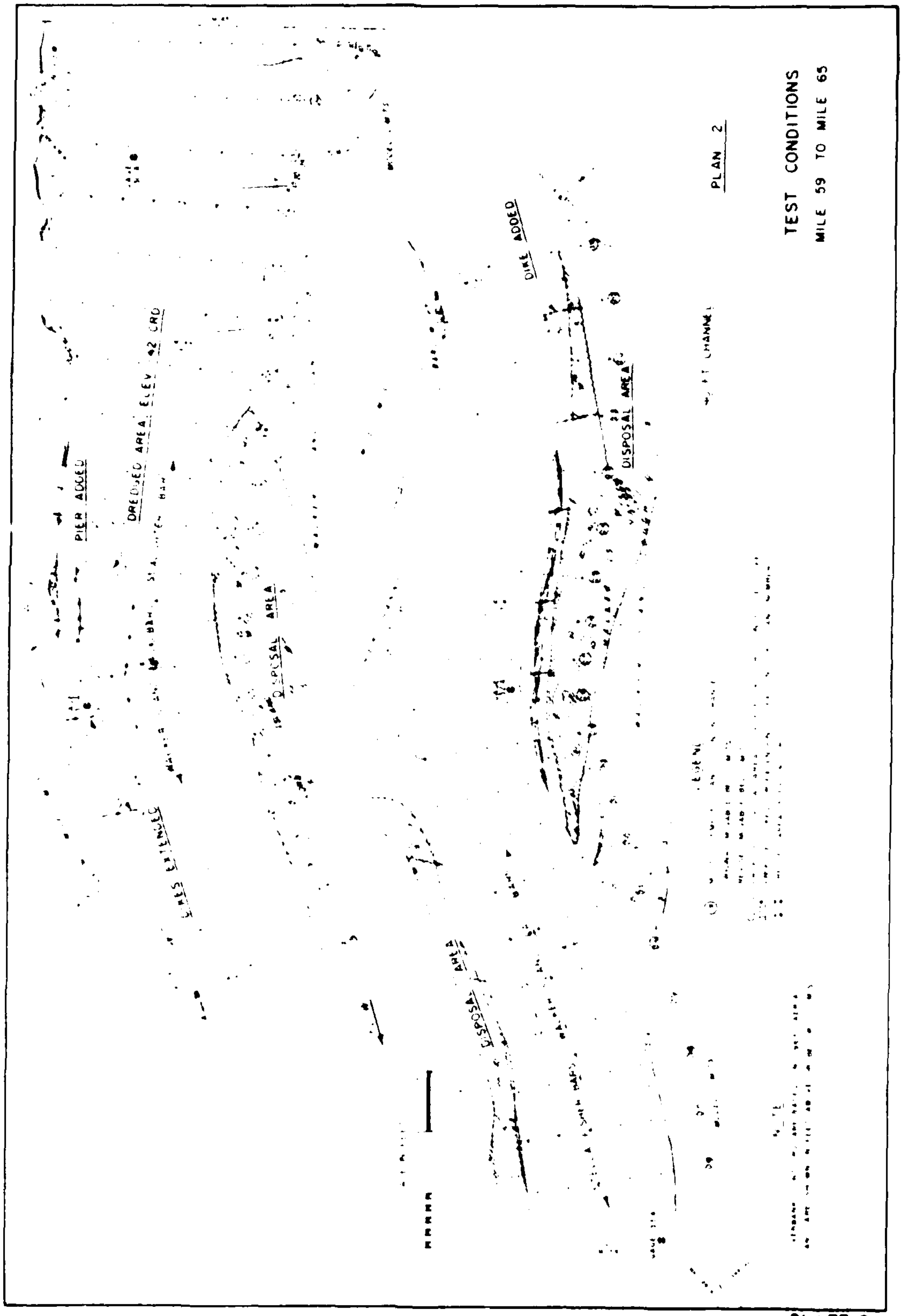
SHOALING DISTRIBUTION
STELLA-FISHER BARS
BASE TESTS

35-AND 40-FT CHANNELS



35- AND 40-FT CHANNELS

SHOALING DISTRIBUTION
GULL ISLAND BAR
BASE TESTS


TEST CONDITIONS
MILE 59 TO MILE 65
PLAN 2
PIER ADDED
DREDGED AREA, ELEV 42 CRD
DIKE ADDED
DISPOSAL AREA
DIKES EXTENDED
LEGEND

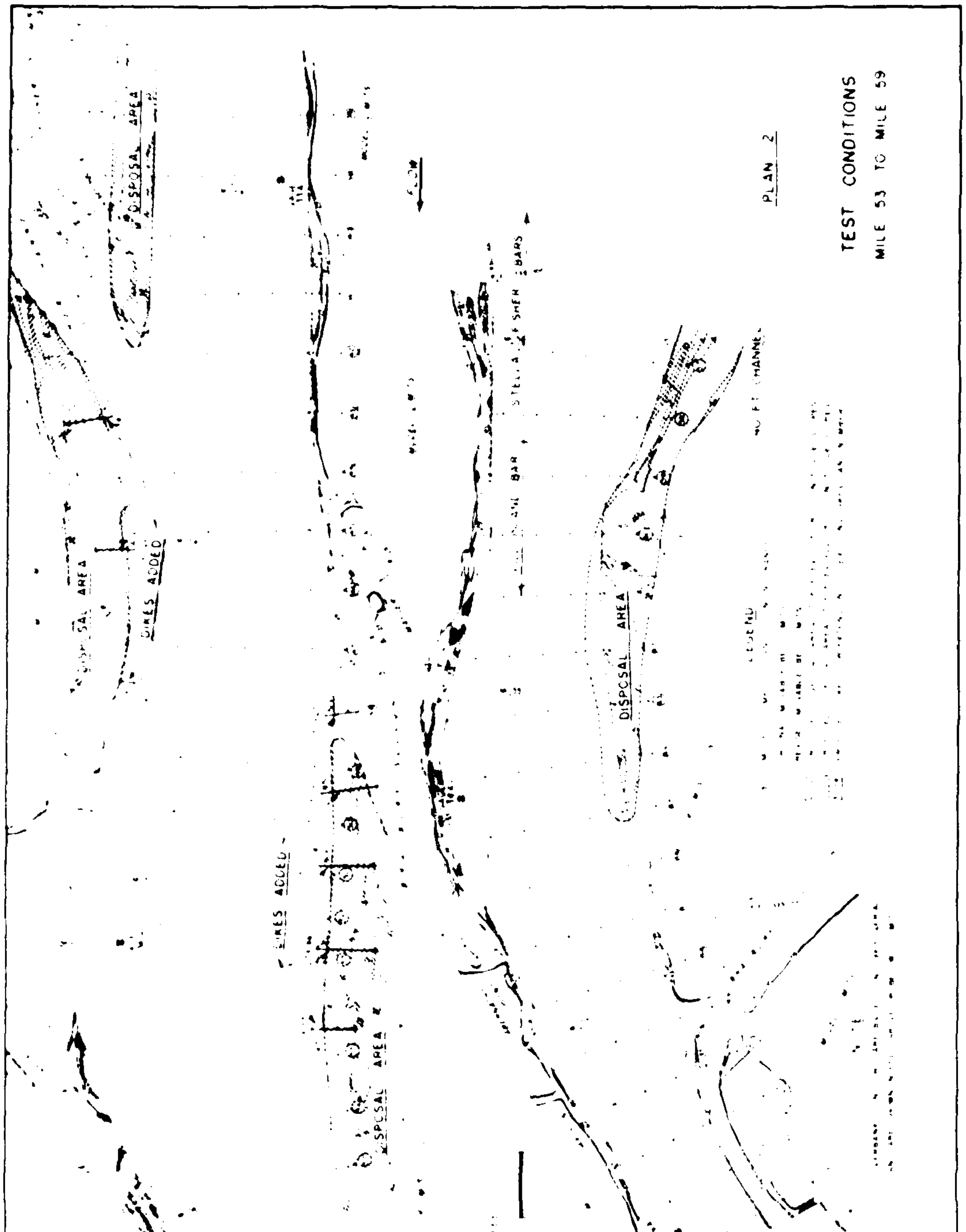

TEST CONDITIONS
MILE 53 TO MILE 59
PLAN 2
FLOW
DISPOSAL AREA
DIKES ADDED
DISPOSAL AREA
DIKES ADDED
DISPOSAL AREA
DISPOSAL AREA
LEGEND

PLATE 37

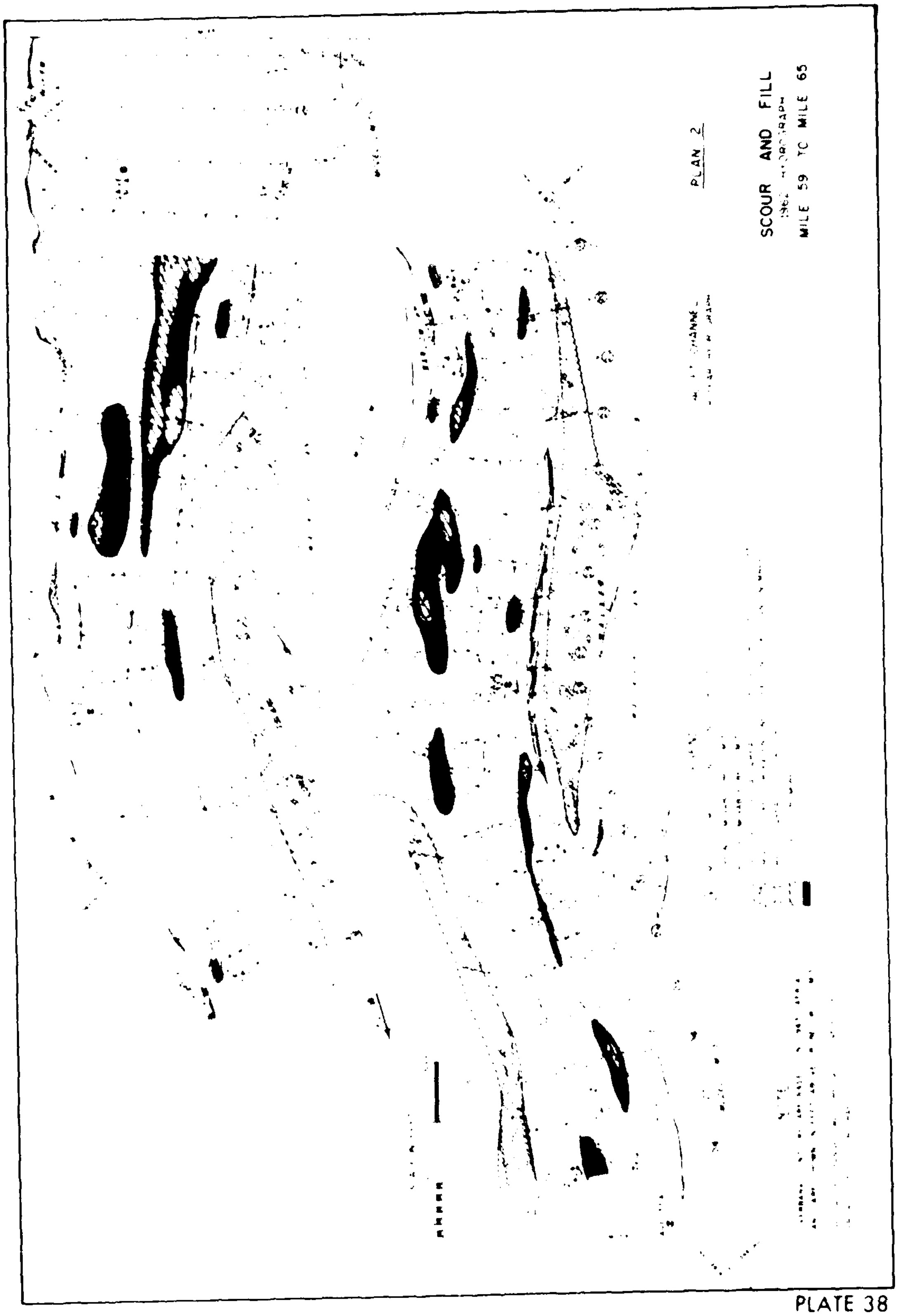


PLATE 38

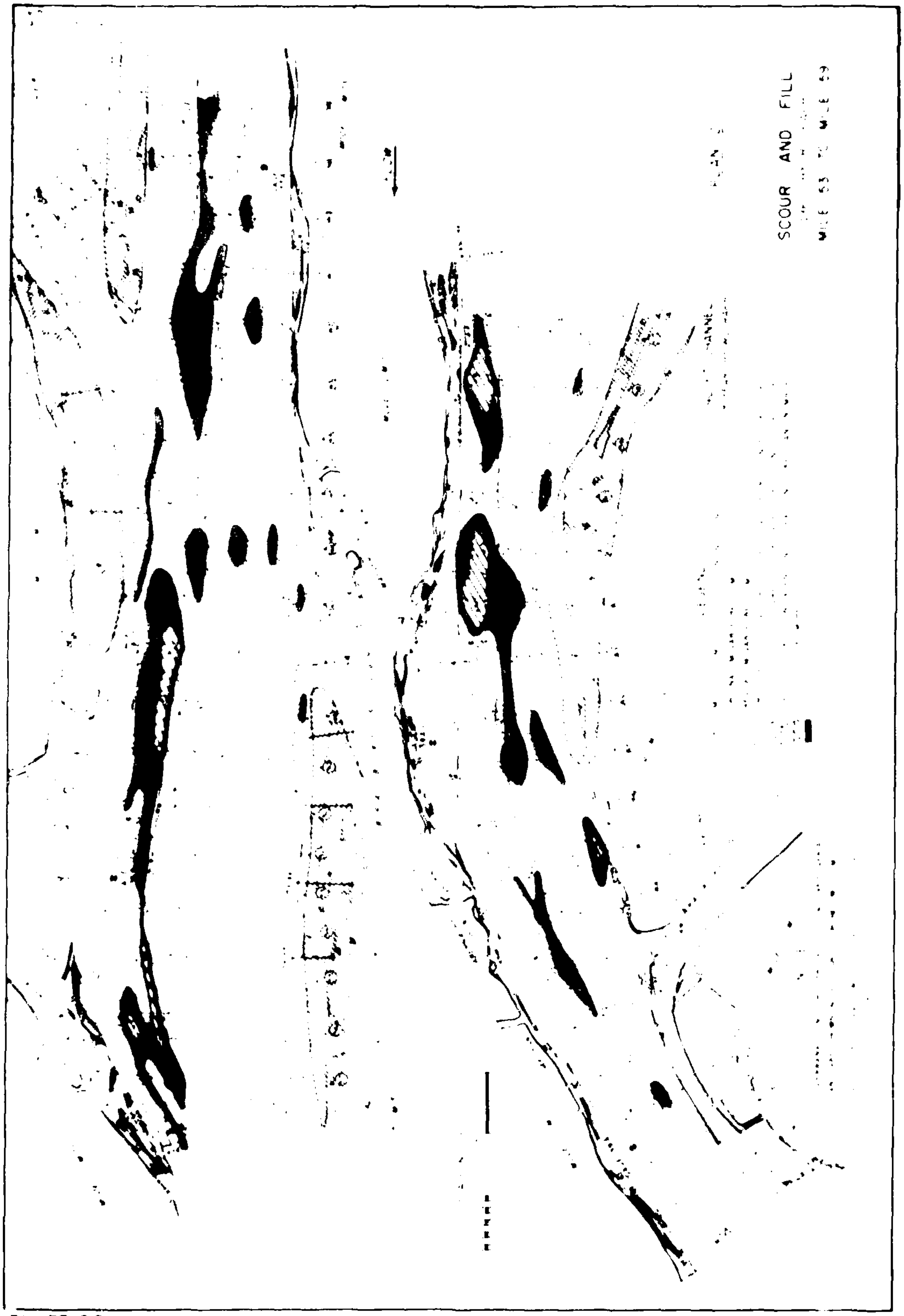
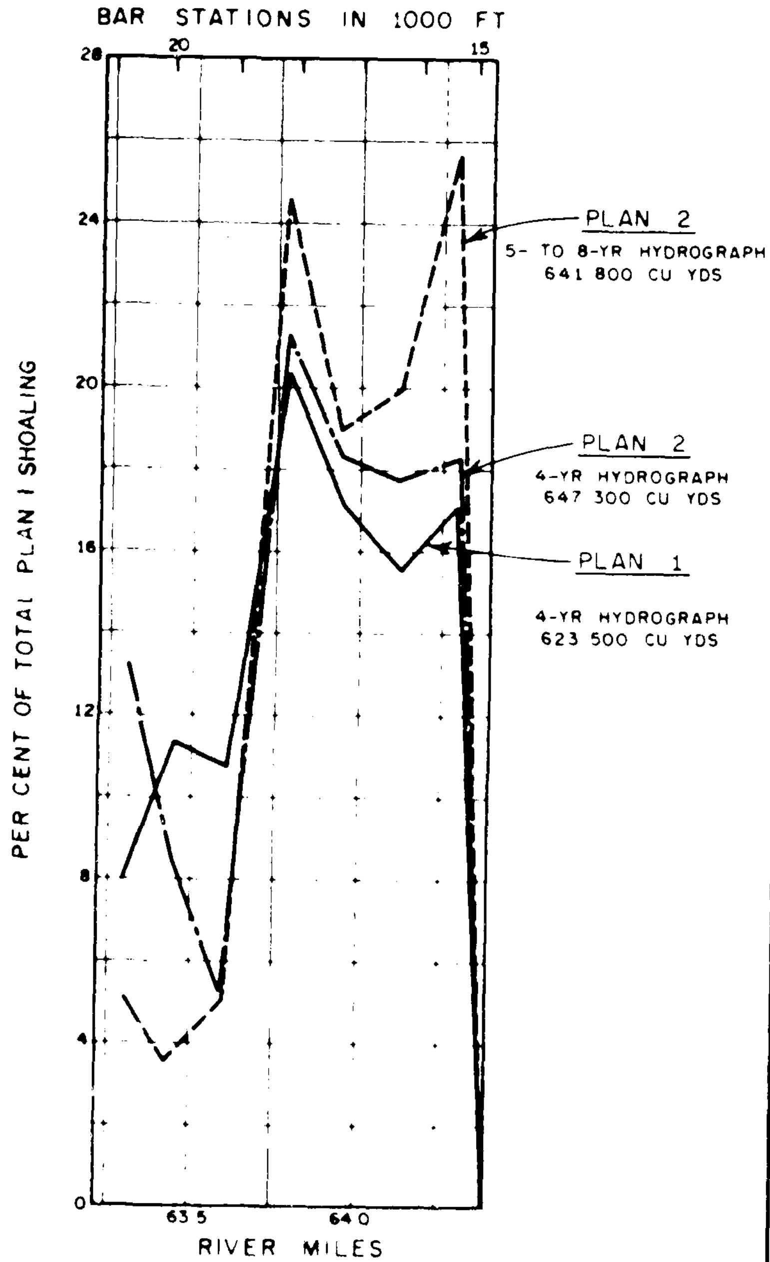


PLATE 39



40-FT CHANNEL

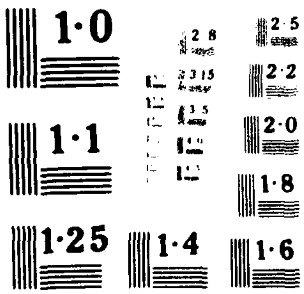
NOTES

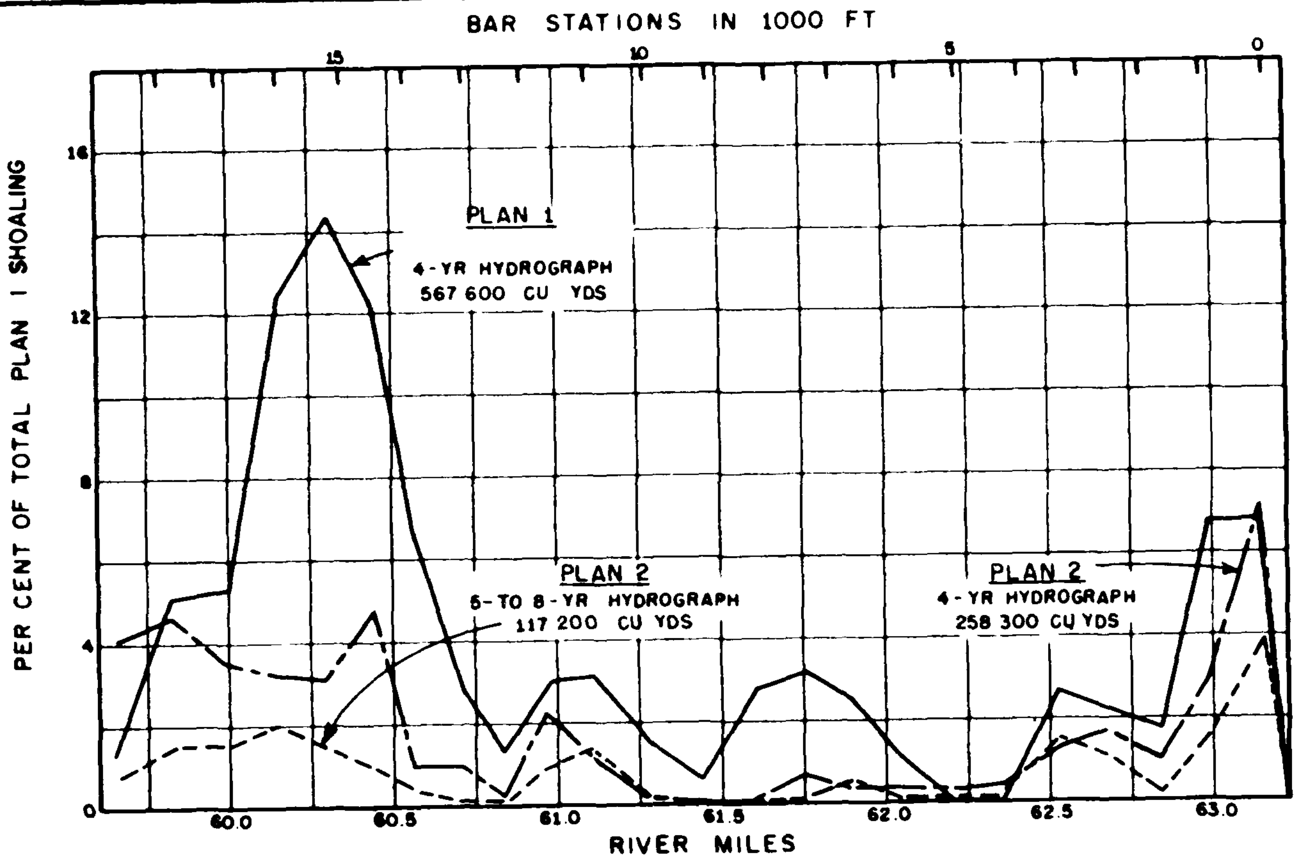
NAVIGATION CHANNEL WAS DREDGED TO 45-FT DEPTH PRIOR TO 5TH HYDROGRAPH

SHOALING DISTRIBUTION
SLAUGHTERS BAR
PLANS 1 AND 2

AD-A149 378   NAVIGATION CHANNEL IMPROVEMENT COLUMBIA RIVER OREGON AND WASHINGTON OAK..(U) ARMY ENGINEER DIV NORTH PACIFIC BONNEVILLE OR DIV HYDRAULIC L.. SEP 84   2/2

UNCLASSIFIED   TR 124 1   F/G 13/2   NL


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5



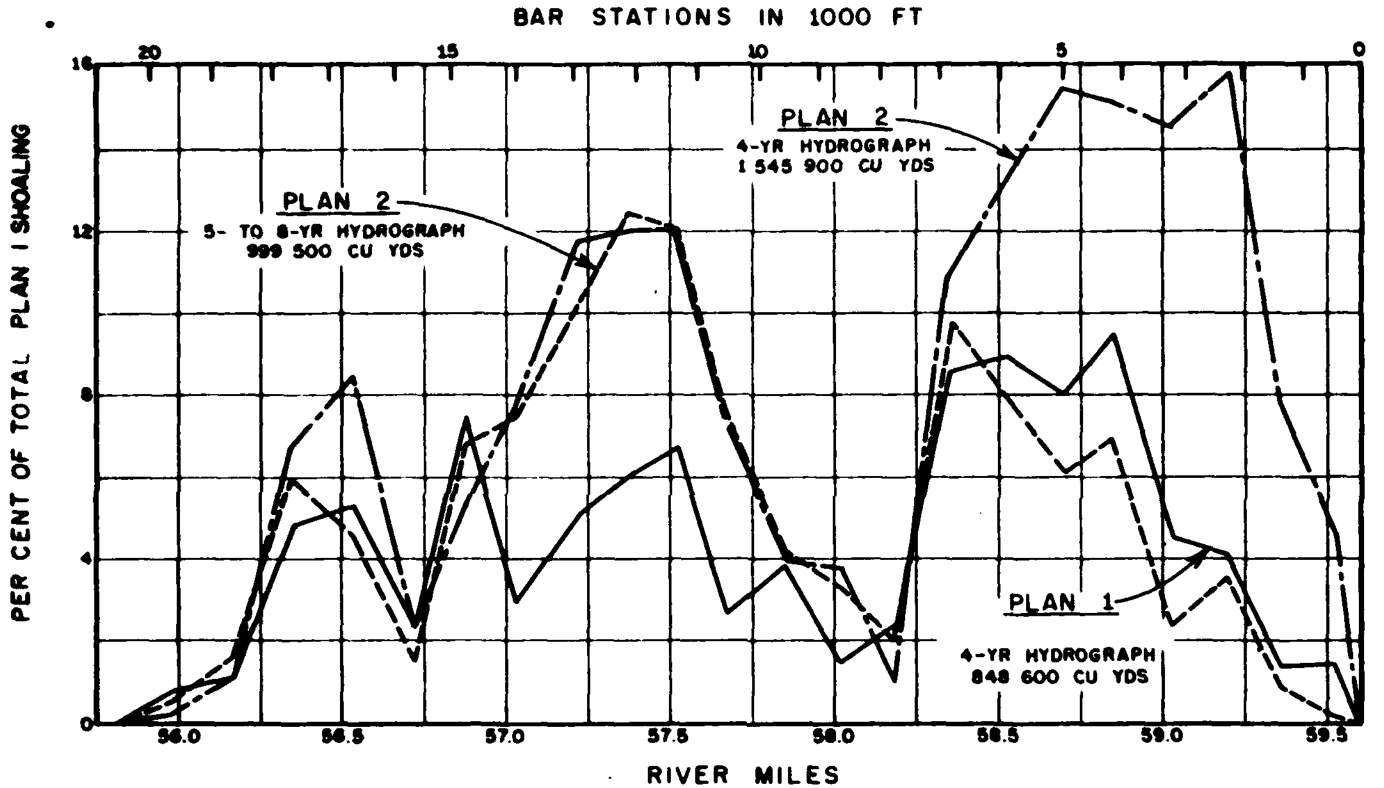
NOTES

NAVIGATION CHANNEL WAS DREDGED
TO 45-FT DEPTH PRIOR TO 5TH HYDROGRAPH.

40-FT CHANNEL

SHOALING DISTRIBUTION
WALKER ISLAND - LA DU BARS
PLANS 1 AND 2

PLATE 41

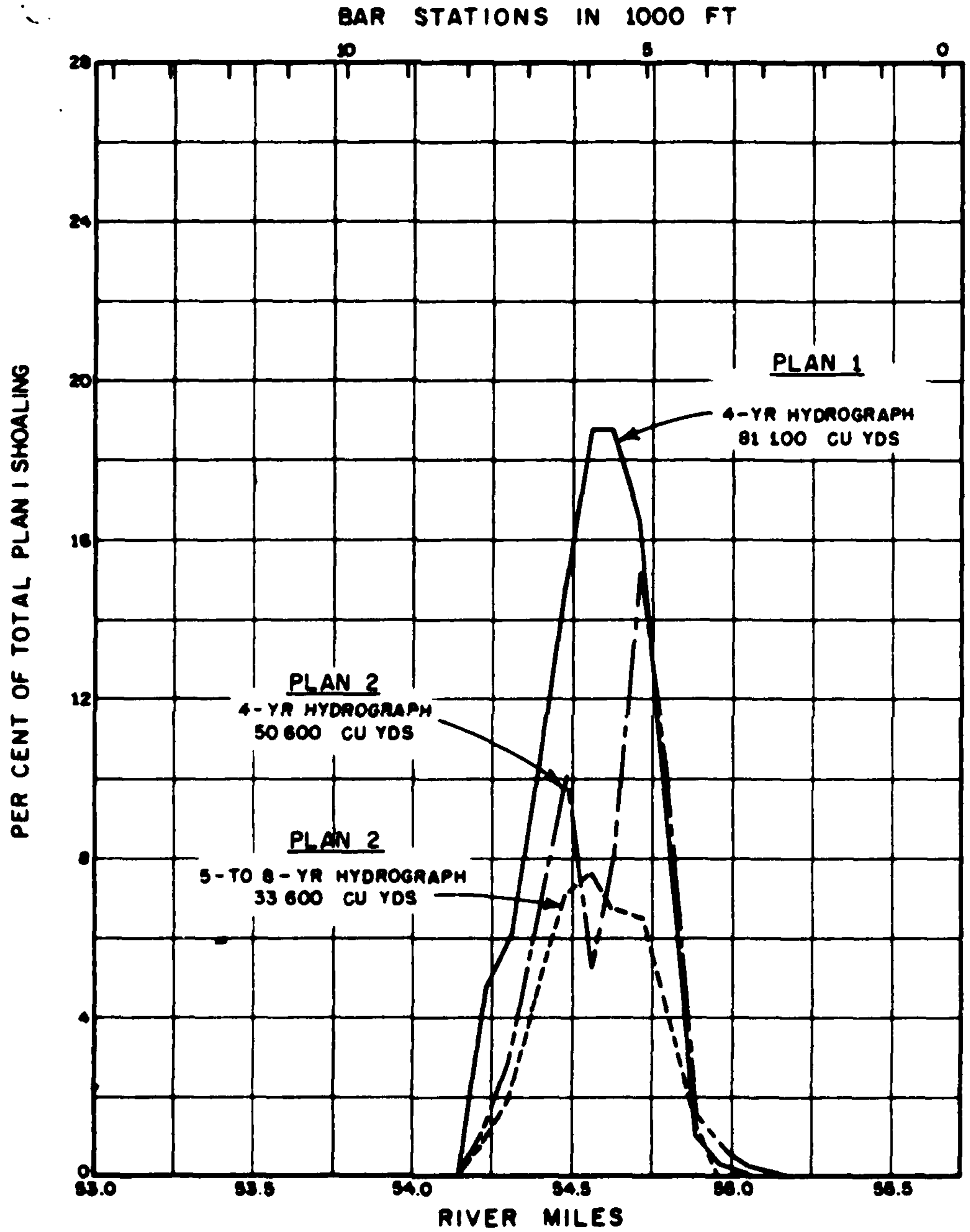


NOTE

NAVIGATION CHANNEL WAS DREDGED TO 45-FT DEPTH PRIOR TO 5TH HYDROGRAPH.

40-FT CHANNEL

SHOALING DISTRIBUTION
STELLA-FISHER BARS
PLANS 1 AND 2



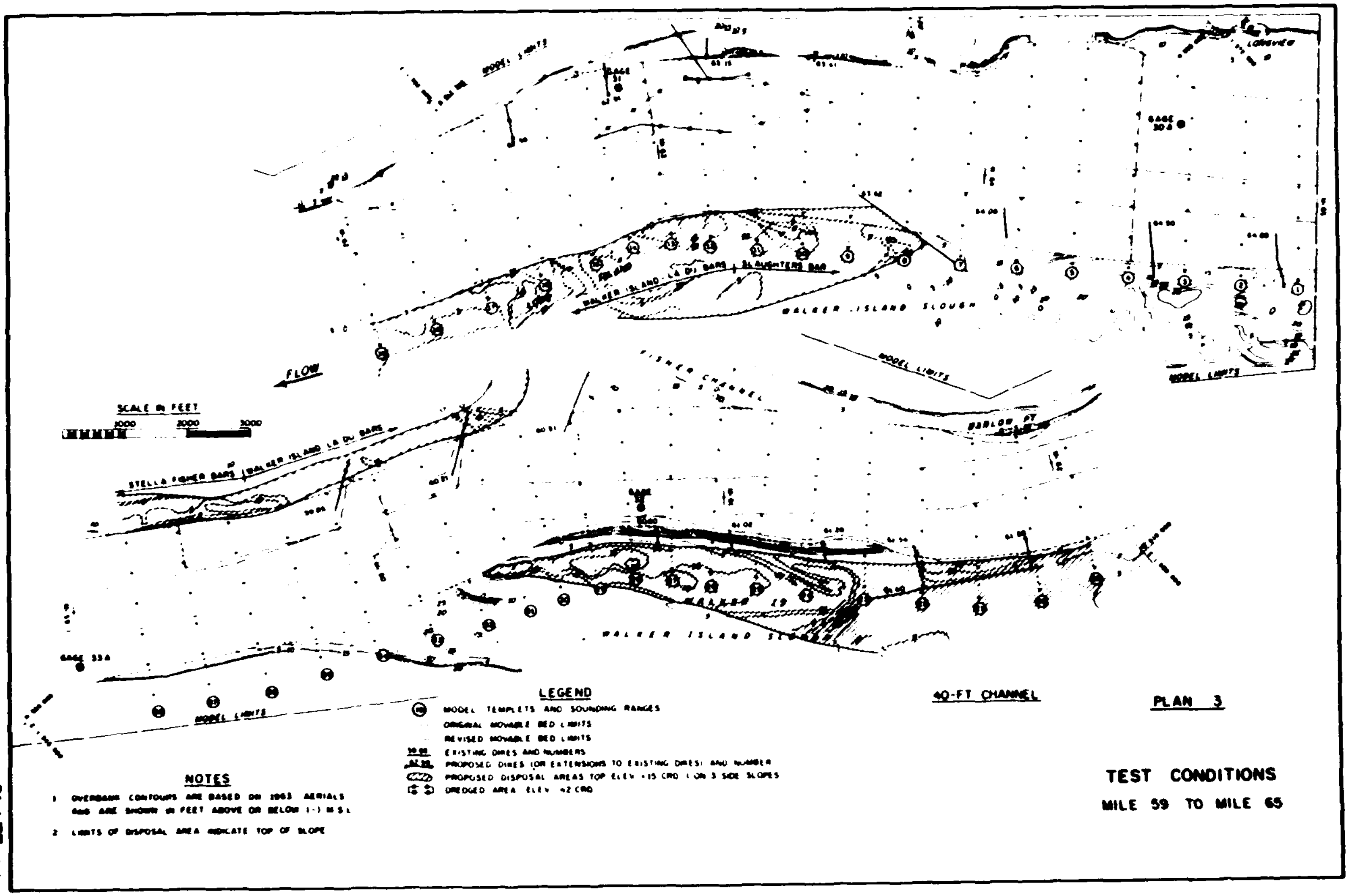
40-FT CHANNEL

NOTE

NAVIGATION CHANNEL WAS DREDGED TO 45-FT DEPTH PRIOR TO 5TH HYDROGRAPH.

SHOALING DISTRIBUTION
GULL ISLAND BAR
PLANS 1 AND 2

PLATE 43



MODEL LIMITS
WALKER ISLAND LA DU BARS SLAUGHTERS BAR
WALKER ISLAND SLOUGH
FISHER CHANNEL
BARLOW PT
FLOW
SCALE IN FEET
1000
2000
3000
STELLA FISHER BARS WALKER ISLAND LA DU BARS
WALKER ISLAND SLOUGH
GAGE 33A
GAGE 30.8
LEGEND
MODEL TEMPLETS AND SOUNDING RANGES
ORIGINAL MOVABLE BED LIMITS
REVISED MOVABLE BED LIMITS
EXISTING DIKES AND NUMBERS
PROPOSED DIKES (OR EXTENSIONS TO EXISTING DIKES) AND NUMBER
PROPOSED DISPOSAL AREAS TOP ELEV +15 CRD 1 ON 3 SIDE SLOPES
DREDGED AREA ELEV -42 CRD
NOTES
1 OVERBANK CONTOURS ARE BASED ON 1963 AERIALS AND ARE SHOWN IN FEET ABOVE OR BELOW (-) M.S.L.
2 LIMITS OF DISPOSAL AREA INDICATE TOP OF SLOPE
40-FT CHANNEL
PLAN 3
TEST CONDITIONS
MILE 59 TO MILE 65

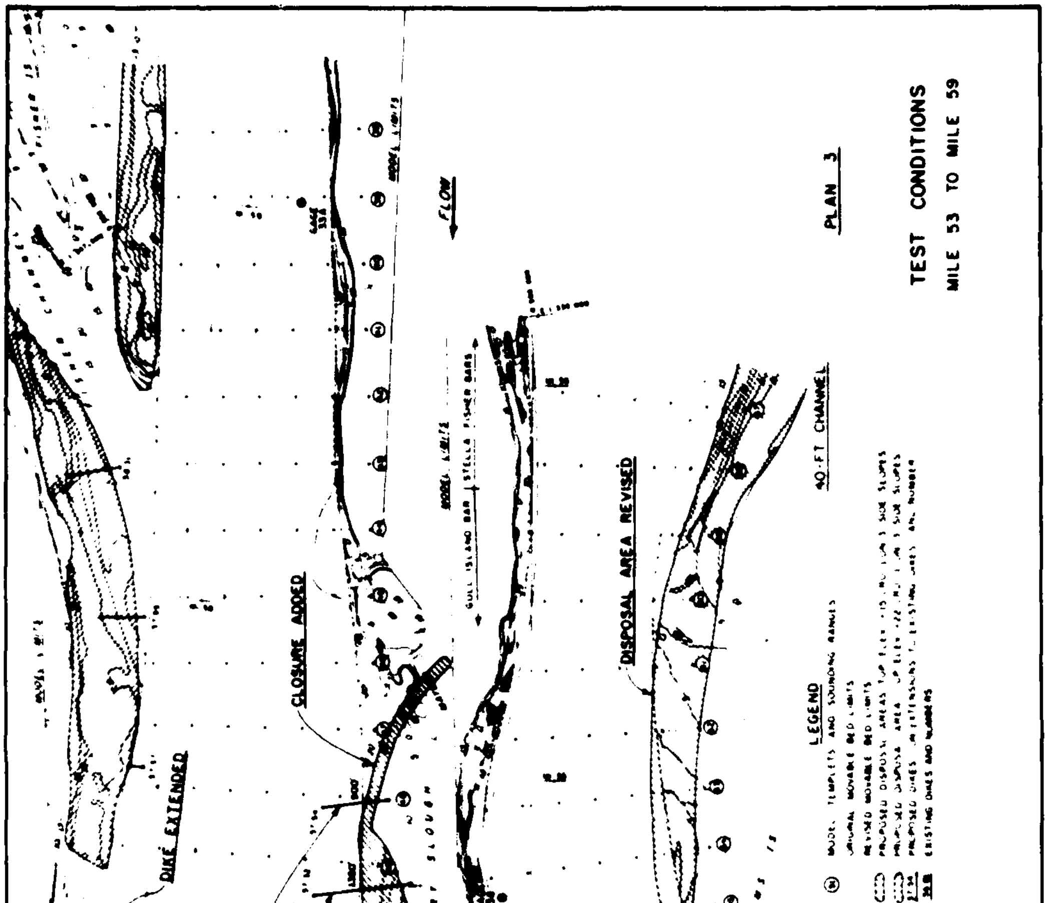
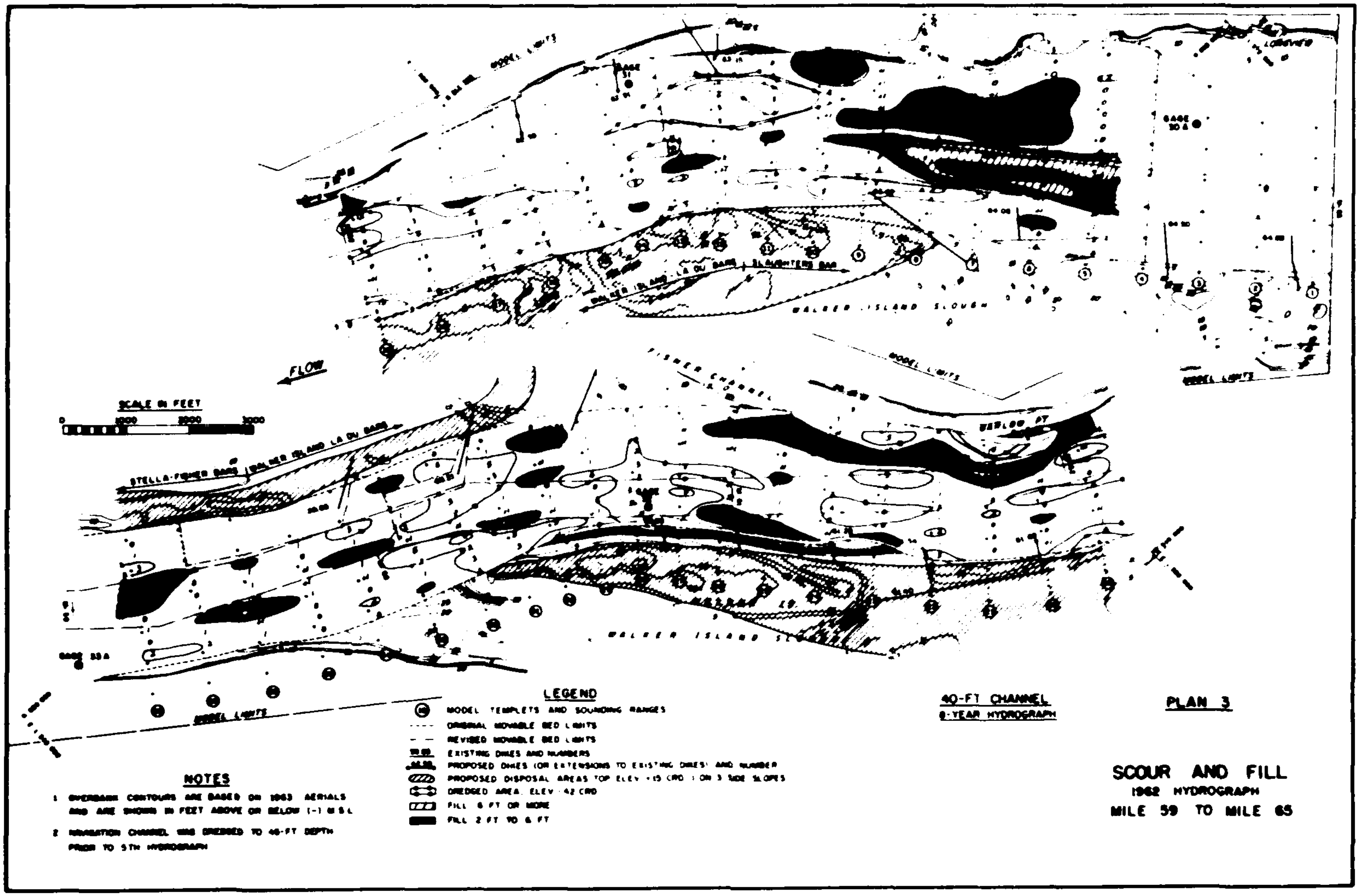
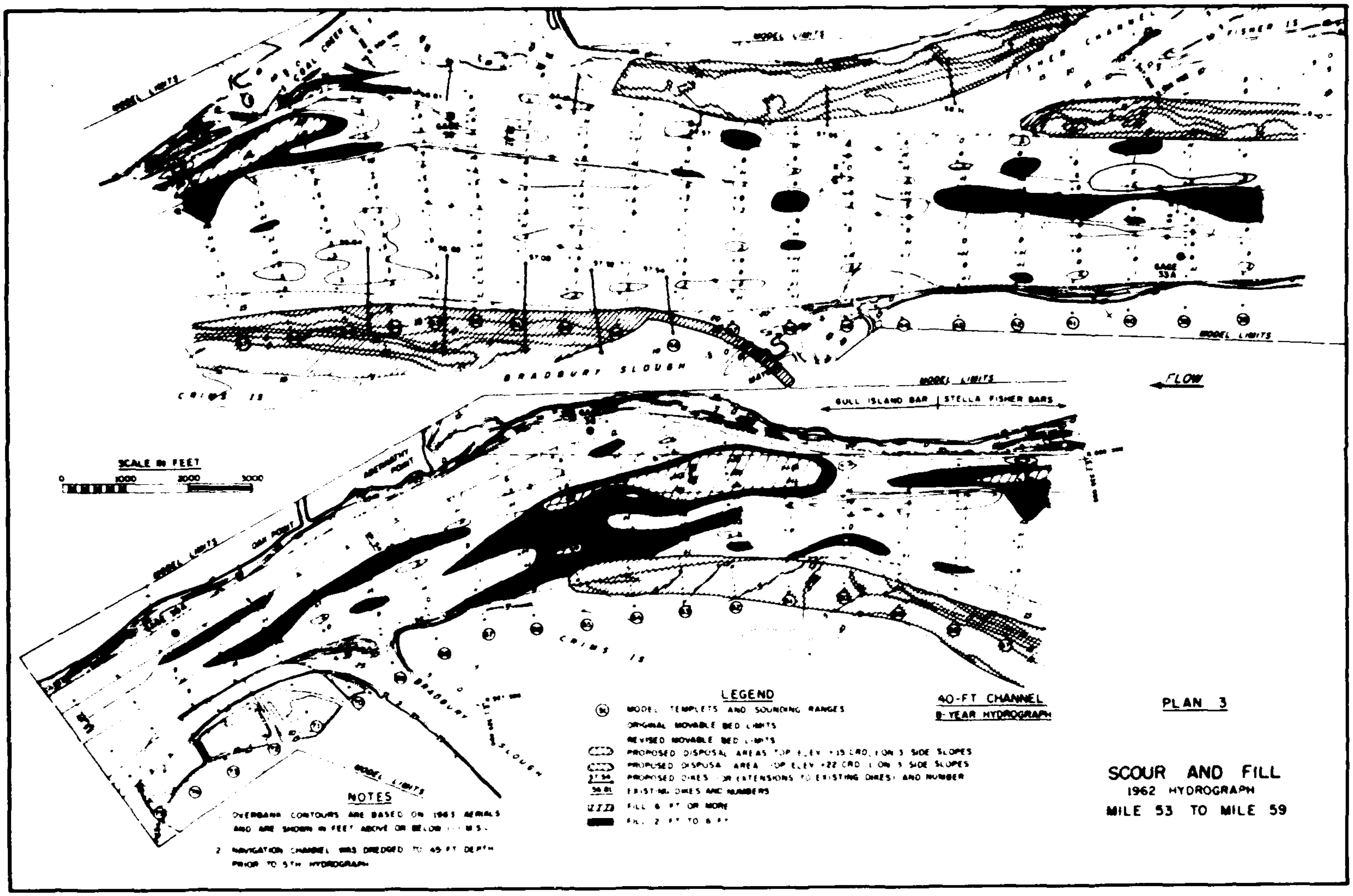

TEST CONDITIONS
MILE 53 TO MILE 59
PLAN 3
40-FT CHANNEL
FLOW
DISPOSAL AREA REVISED
CLOSURE ADDED
DIKE EXTENDED
DIKES EXTENDED
LEGEND
NOTES
SCALE IN FEET

PLATE 45



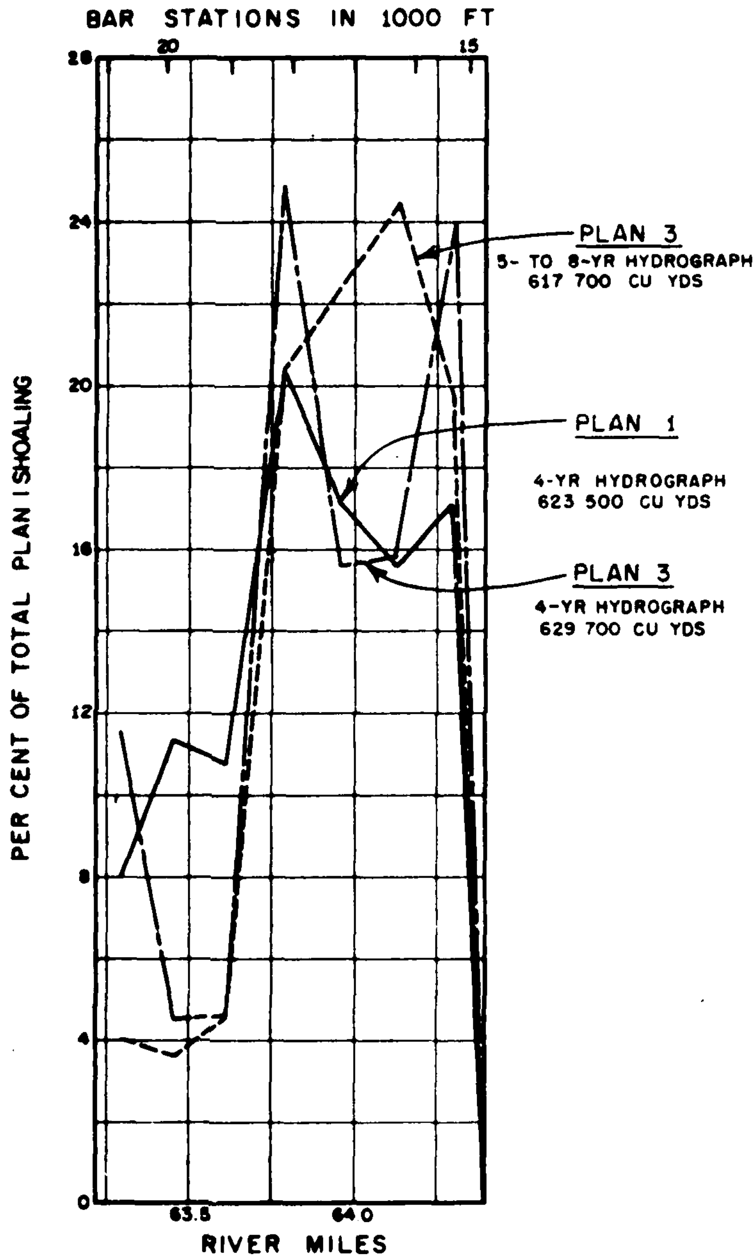
MODEL LIMITS
FLOW
SCALE IN FEET
0
1000
2000
3000
STELLA-FISHER BARS
WALKER ISLAND LA DU BARS
SLAUGHTERS BAR
WALKER ISLAND SLOUGH
FISHER CHANNEL
GAGE 33 A
GAGE 30 A
LEGEND
MODEL TEMPLETS AND SOUNDING RANGES
ORIGINAL MOVABLE BED LIMITS
REVISED MOVABLE BED LIMITS
EXISTING DIKES AND NUMBERS
PROPOSED DIKES (OR EXTENSIONS TO EXISTING DIKES) AND NUMBER
PROPOSED DISPOSAL AREAS TOP ELEV +15 CRD 1 ON 3 SIDE SLOPES
DREDGED AREA. ELEV -42 CRD
FILL 6 FT OR MORE
FILL 2 FT TO 6 FT
NOTES
1 OVERBANK CONTOURS ARE BASED ON 1963 AERIALS AND ARE SHOWN IN FEET ABOVE OR BELOW (-) M S L
2 NAVIGATION CHANNEL WAS DREDGED TO 46-FT DEPTH PRIOR TO 5TH HYDROGRAPH
40-FT CHANNEL
8-YEAR HYDROGRAPH
PLAN 3
SCOUR AND FILL
1962 HYDROGRAPH
MILE 59 TO MILE 65

PLATE 46



MODEL LIMITS
FISHER IS
FISHER CHANNEL
BRADBURY SLOUGH
CRIMS IS
FLOW
GULL ISLAND BAR | STELLA FISHER BARS
GAGE 53A
SCALE IN FEET
0 1000 2000 3000
LEGEND
MODEL TEMPLETS AND SOUNDING RANGES
ORIGINAL MOVABLE BED LIMITS
REVISED MOVABLE BED LIMITS
EXISTING DIKES AND NUMBERS
FILL 6 FT OR MORE
FILL 2 FT TO 6 FT
40-FT CHANNEL
8-YEAR HYDROGRAPH
PLAN 3
NOTES
SCOUR AND FILL
1962 HYDROGRAPH
MILE 53 TO MILE 59

PLATE 47



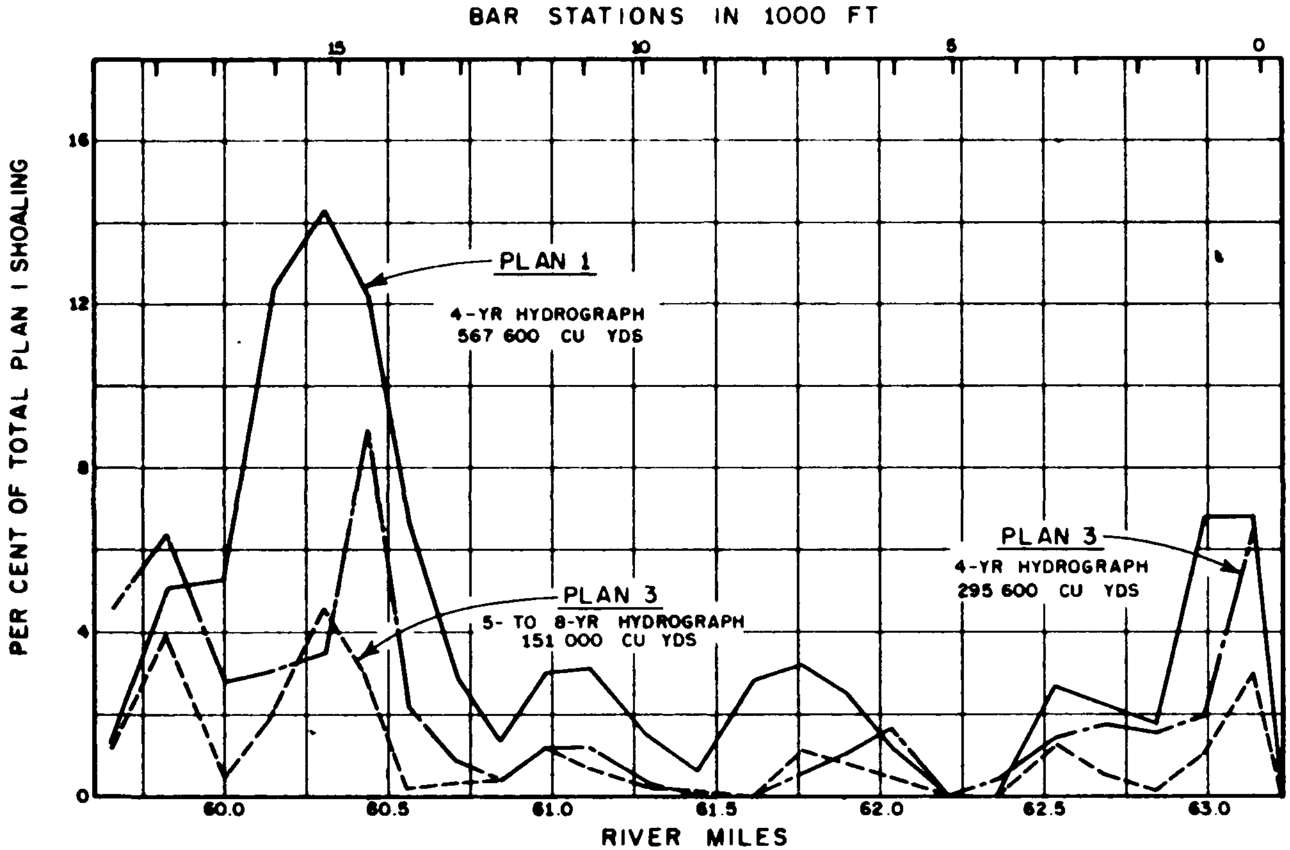
40-FT CHANNEL

NOTES

NAVIGATION CHANNEL WAS DREDGED TO 45-FT DEPTH PRIOR TO 5TH AND 9TH HYDROGRAPHS.

QUANTITIES ARE SHOALING IN THE NAVIGATION CHANNEL ABOVE ELEVATION -45 CRD (40 FT PLUS 5-FT OVERDEPTH).

SHOALING DISTRIBUTION
SLAUGHTERS BAR
PLANS 1 AND 3



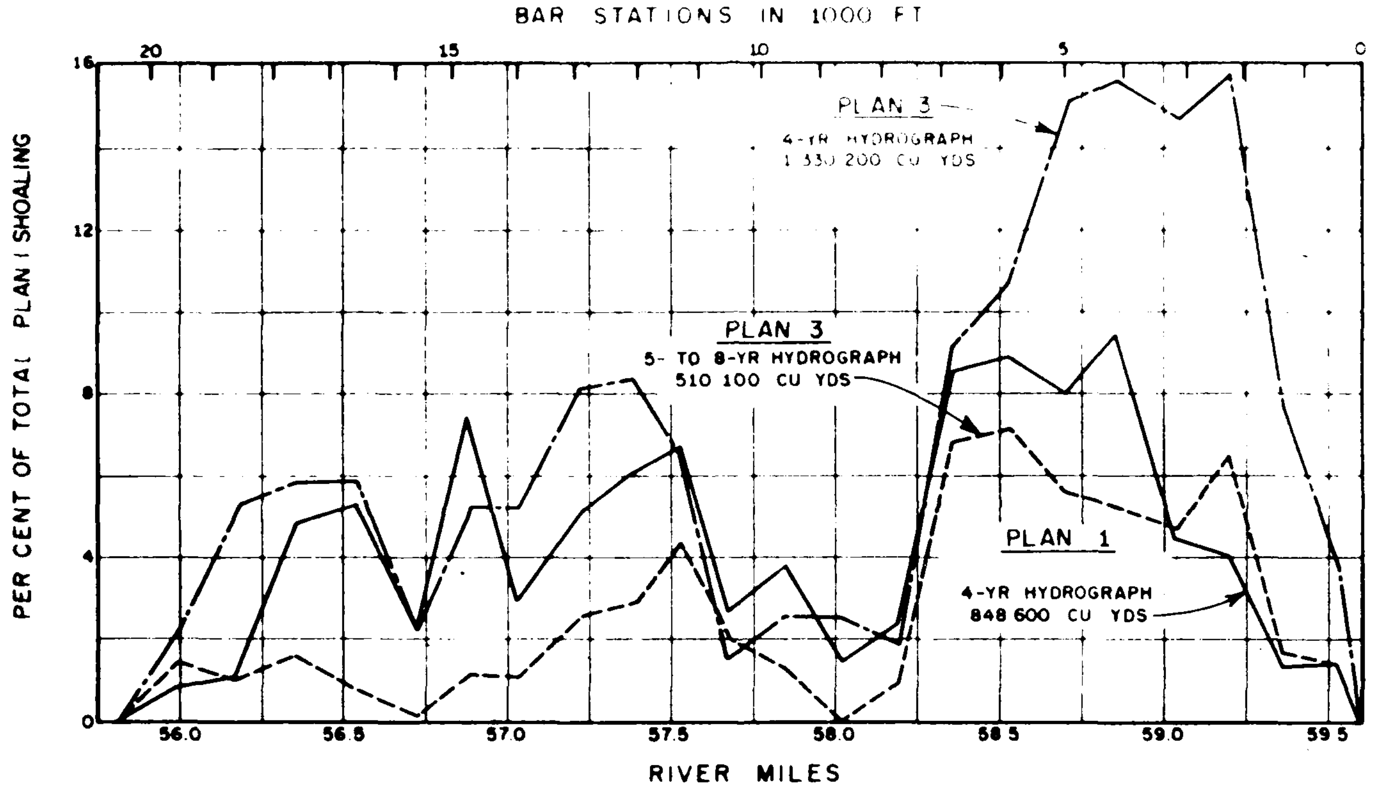
NOTES

NAVIGATION CHANNEL WAS DREDGED TO 45-FT DEPTH PRIOR TO 5TH AND 9TH HYDROGRAPHS

QUANTITIES ARE SHOALING IN THE NAVIGATION CHANNEL ABOVE ELEVATION -45 CRD (40 FT PLUS 5-FT OVERDEPTH)

40-FT CHANNEL

SHOALING DISTRIBUTION
WALKER ISLAND - LA DU BARS
PLANS 1 AND 3



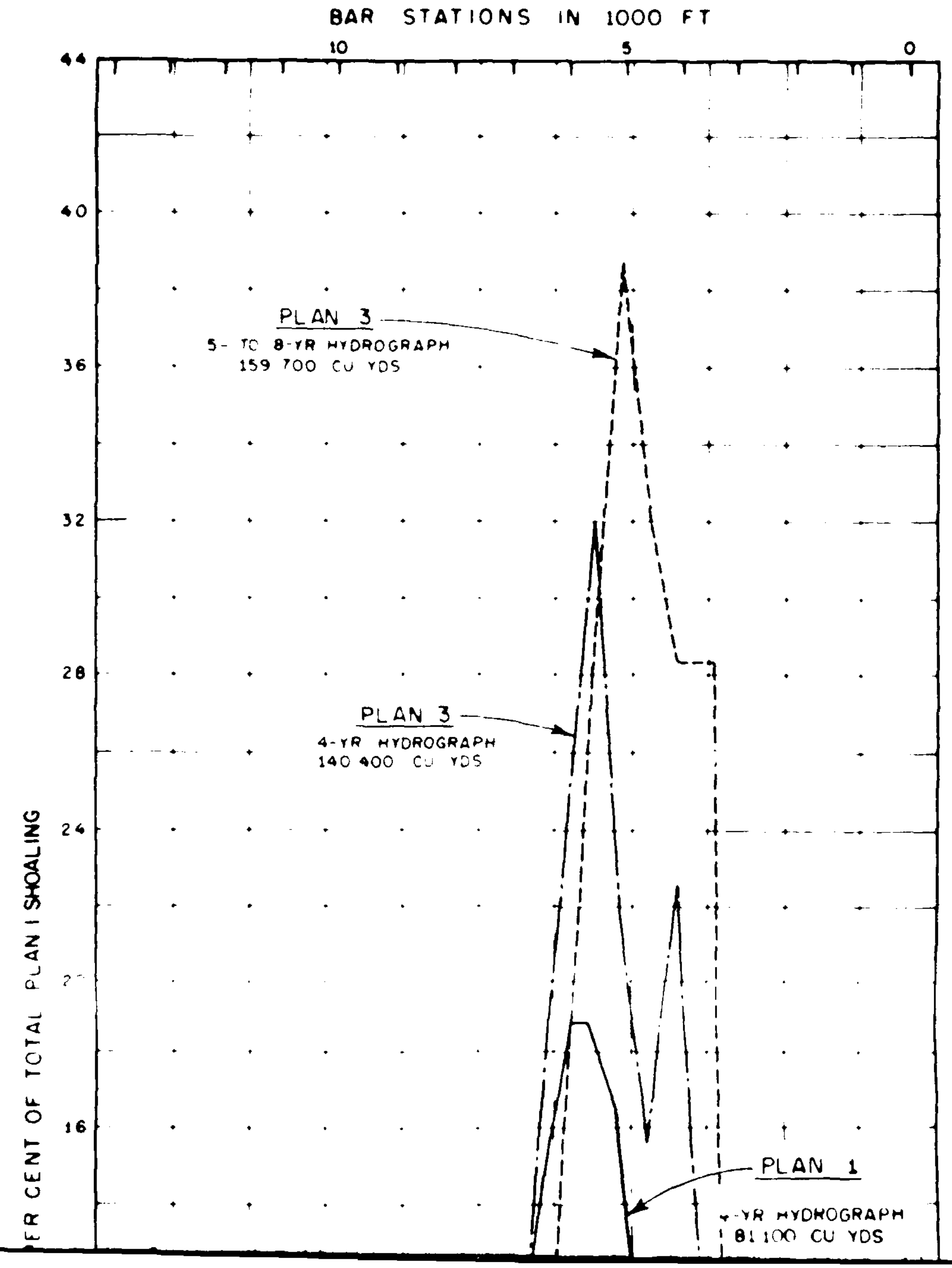
SHOALING DISTRIBUTION
STELLA-FISHER BARS
PLANS 1 AND 3

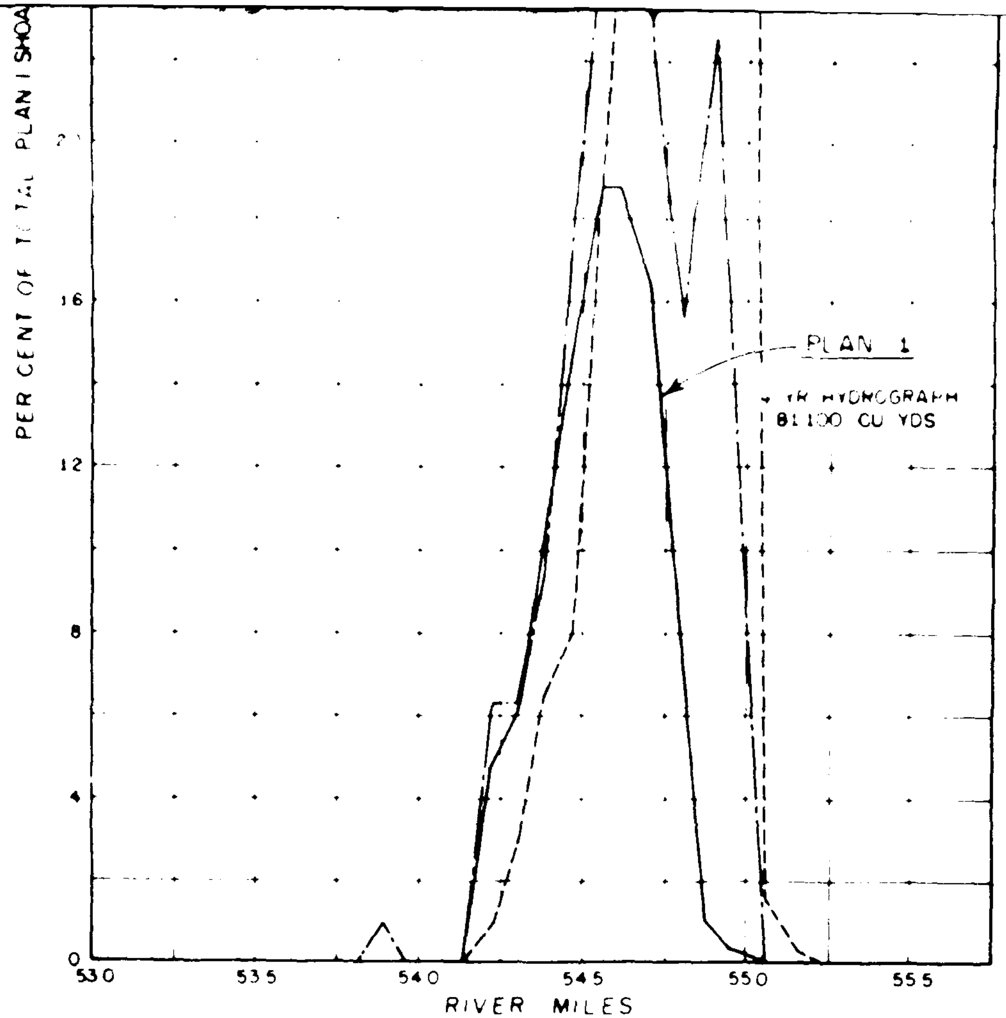
40-FT CHANNEL

NOTES

NAVIGATION CHANNEL WAS DREDGED TO 45-FT DEPTH PRIOR TO 5TH AND 9TH HYDROGRAPHS.

QUANTITIES ARE SHOALING IN THE NAVIGATION CHANNEL ABOVE ELEVATION -45 CRD (40 FT PLUS 5-FT OVERDEPTH).


BAR STATIONS IN 1000 FT
10
5
0
44
40
36
32
28
24
16
PLAN 3
5- TO 8-YR HYDROGRAPH
159 700 CU YDS
PLAN 3
4-YR HYDROGRAPH
140 400 CU YDS
PLAN 1
81 100 CU YDS
ER CENT OF TOTAL PLAN I SHOALING



40-FT CHANNEL

NOTES

NAVIGATION CHANNEL WAS DREDGED TO 45-FT DEPTH PRIOR TO 5TH AND 9TH HYDROGRAPHS

QUANTITIES ARE SHOALING IN THE NAVIGATION CHANNEL ABOVE ELEVATION -45 CRD (40 FT PLUS 5-FT OVERDEPTH)

SHOALING DISTRIBUTION

GULL ISLAND BAR

PLANS 1 AND 3

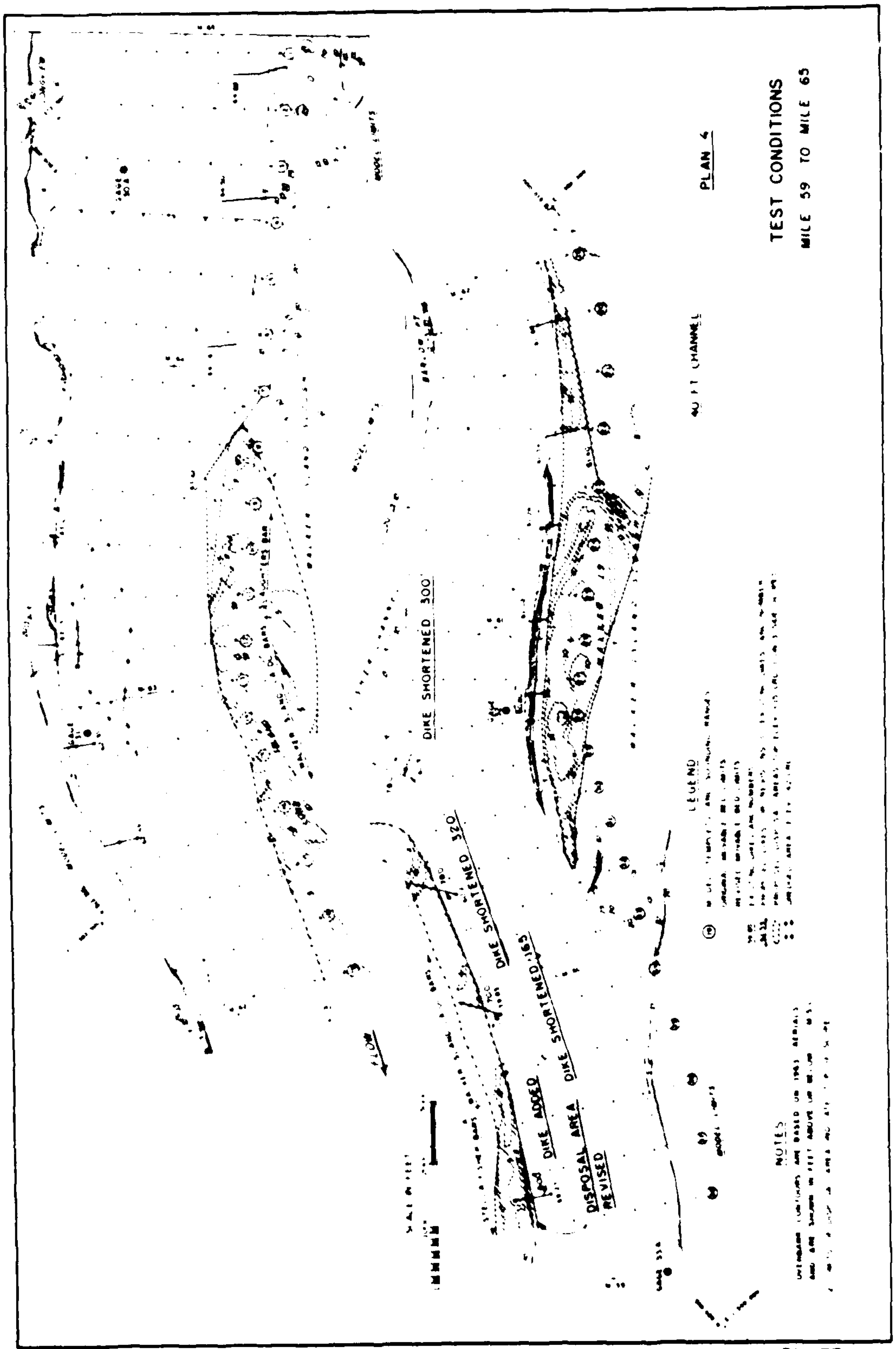

TEST CONDITIONS
MILE 59 TO MILE 65
PLAN 4
40 FT CHANNEL
DIKE SHORTENED 300
DIKE SHORTENED 320
DIKE SHORTENED 165
DIKE ADDED
DISPOSAL AREA
REVISED
FLOW
LEGEND
NOTES

PLATE 52

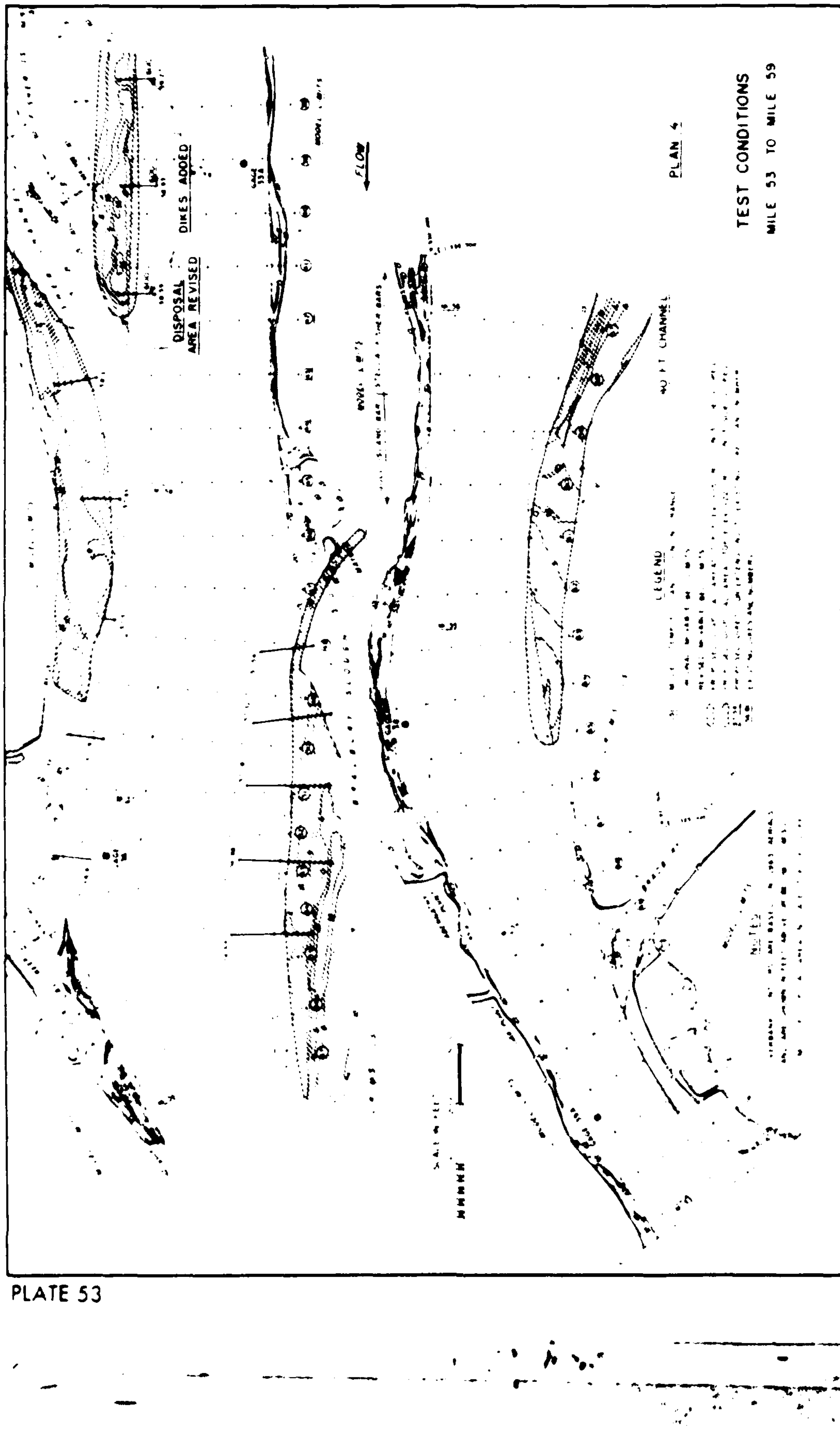

TEST CONDITIONS
MILE 53 TO MILE 59
PLAN 4
FLOW
DISPOSAL AREA REVISED
DIKES ADDED
LEGEND
NOTES
40 FT CHANNEL

PLATE 53

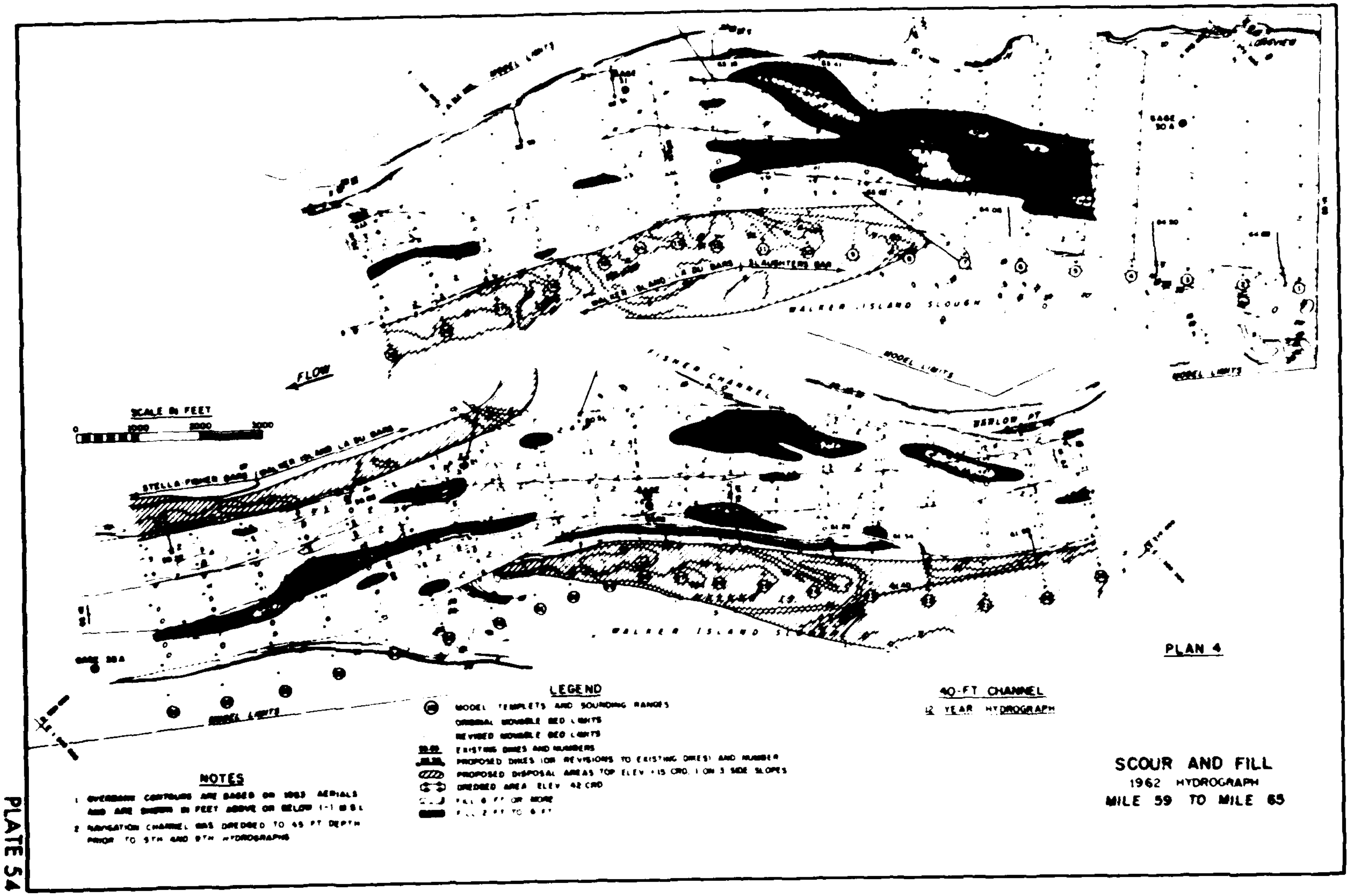
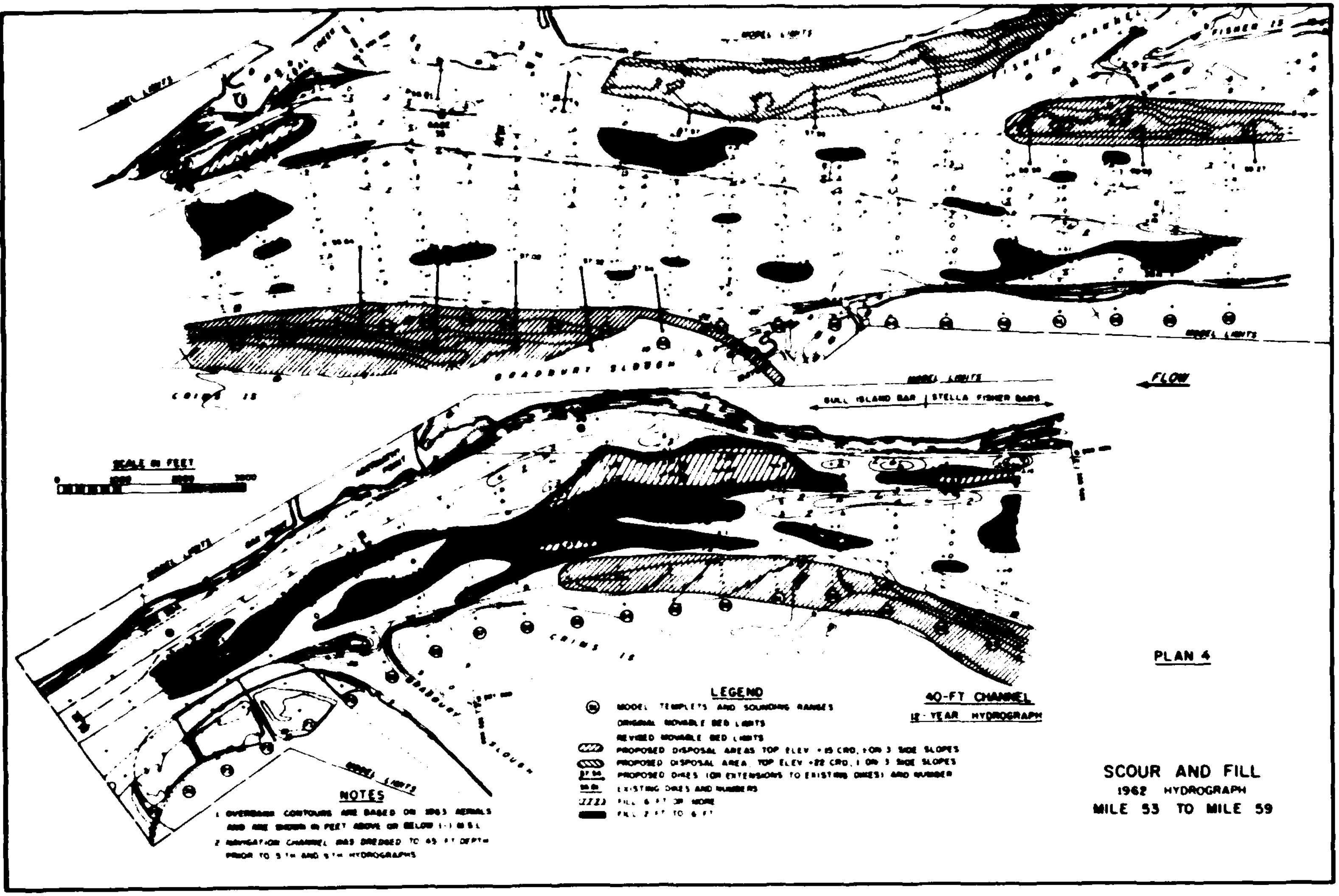
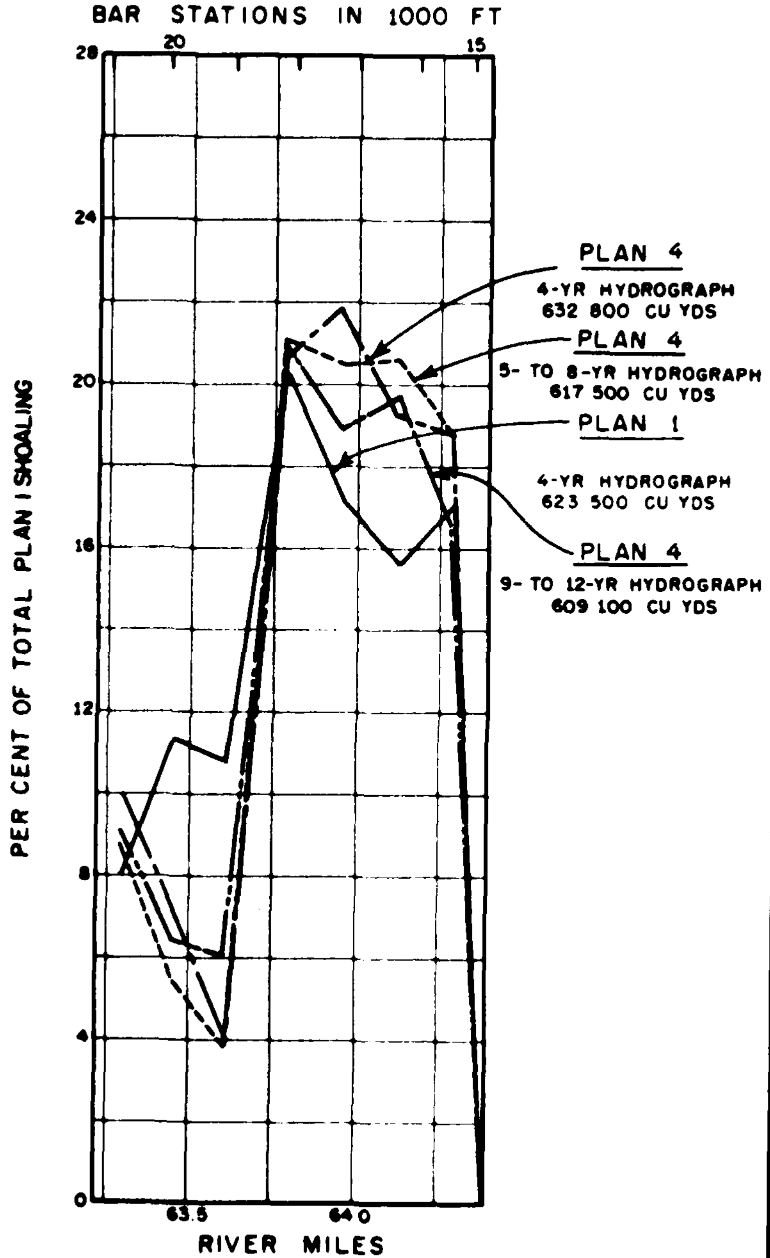

SCOUR AND FILL
1962 HYDROGRAPH
MILE 59 TO MILE 65
PLAN 4
40-FT CHANNEL
12 YEAR HYDROGRAPH
LEGEND
MODEL TEMPLETS AND SOUNDING RANGES
ORIGINAL MOVABLE BED LIMITS
REVISED MOVABLE BED LIMITS
EXISTING DIKES AND NUMBERS
PROPOSED DIKES (OR REVISIONS TO EXISTING DIKES) AND NUMBER
PROPOSED DISPOSAL AREAS TOP ELEV +15 CRD, 1 ON 3 SIDE SLOPES
DREDGED AREA ELEV 42 CRD
FILL 6 FT OR MORE
FILL 2 FT TO 6 FT
NOTES
1 OVERBANK CONTOURS ARE BASED ON 1963 AERIALS AND ARE SHOWN IN FEET ABOVE OR BELOW 1-1 MSL
2 NAVIGATION CHANNEL WAS DREDGED TO 45 FT DEPTH PRIOR TO 5TH AND 8TH HYDROGRAPHS
SCALE IN FEET
0
1000
2000
3000
FLOW
MODEL LIMITS
WALKER ISLAND SLOUGH
FISHER CHANNEL
STELLA-FISHER BARS
GAGE 30 A
SLAUGHTERS BAR

PLATE 54

PLATE 55


MODEL LIGHTS
FLOW
BULL ISLAND BAR
STELLA FISHER BARS
BRADBURY SLOUGH
CRIMS IS
SCALE IN FEET
0
1000
2000
3000
LEGEND
MODEL TEMPLETS AND SOUNDING RANGES
ORIGINAL MOVABLE BED LIMITS
REVISED MOVABLE BED LIMITS
PROPOSED DISPOSAL AREAS TOP ELEV +15 CRD, 1 ON 3 SIDE SLOPES
PROPOSED DISPOSAL AREA TOP ELEV +22 CRD, 1 ON 3 SIDE SLOPES
PROPOSED DIKES (OR EXTENSIONS TO EXISTING DIKES) AND NUMBER
EXISTING DIKES AND NUMBERS
FILL 6 FT OR MORE
FILL 2 FT TO 6 FT
NOTES
1. OVERBANK CONTOURS ARE BASED ON 1963 AERIALS AND ARE SHOWN IN FEET ABOVE OR BELOW (-) M.S.L.
2. NAVIGATION CHANNEL WAS DREDGED TO 45 FT DEPTH PRIOR TO 5TH AND 6TH HYDROGRAPHS
40-FT CHANNEL
12-YEAR HYDROGRAPH
PLAN 4
SCOUR AND FILL
1962 HYDROGRAPH
MILE 53 TO MILE 59



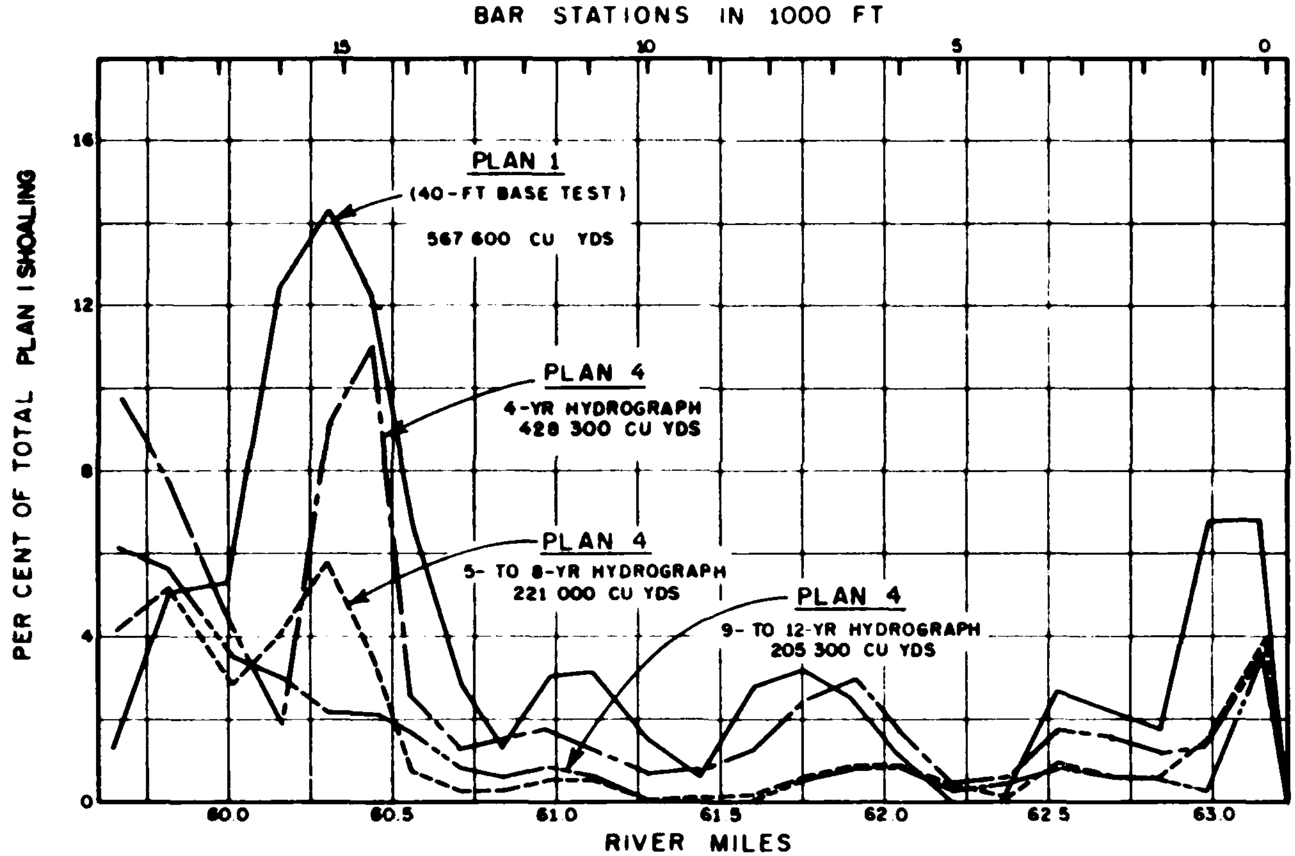
40-FT CHANNEL

NOTES

NAVIGATION CHANNEL WAS DREDGED TO 45-FT DEPTH PRIOR TO 5TH AND 9TH HYDROGRAPHS

QUANTITIES ARE SHOALING IN THE NAVIGATION CHANNEL ABOVE ELEVATION -45 CRD (40 FT PLUS 5-FT OVERDEPTH).

SHOALING DISTRIBUTION
SLAUGHTERS BAR
PLANS 1 AND 4



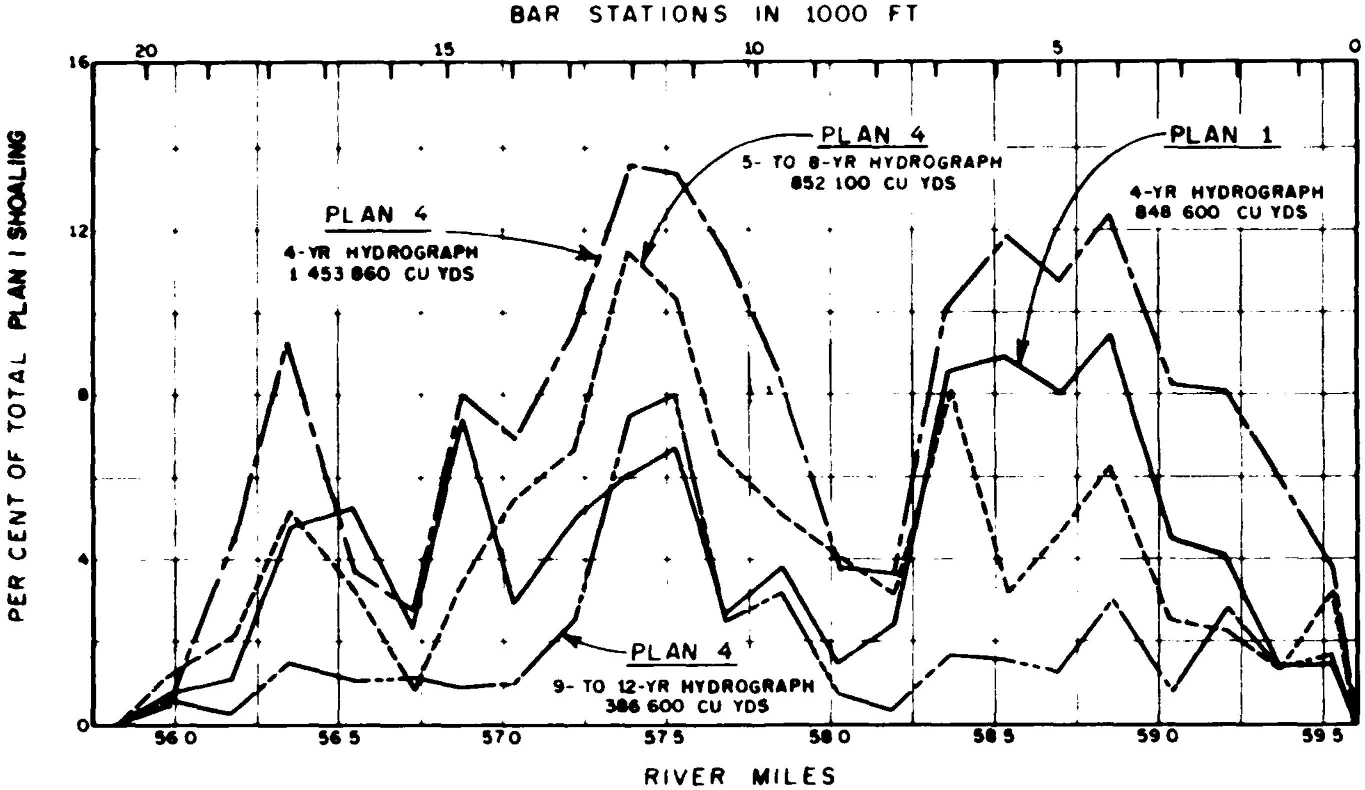
NOTES

NAVIGATION CHANNEL WAS DREDGED TO 45-FT DEPTH PRIOR TO 5TH AND 9TH HYDROGRAPHS.

QUANTITIES ARE SHOALING IN THE NAVIGATION CHANNEL ABOVE ELEVATION -45 CRD (40 FT PLUS 5-FT OVERDEPTH).

40-FT CHANNEL

SHOALING DISTRIBUTION
WALKER ISLAND - LA DU BARS
PLANS 1 AND 4



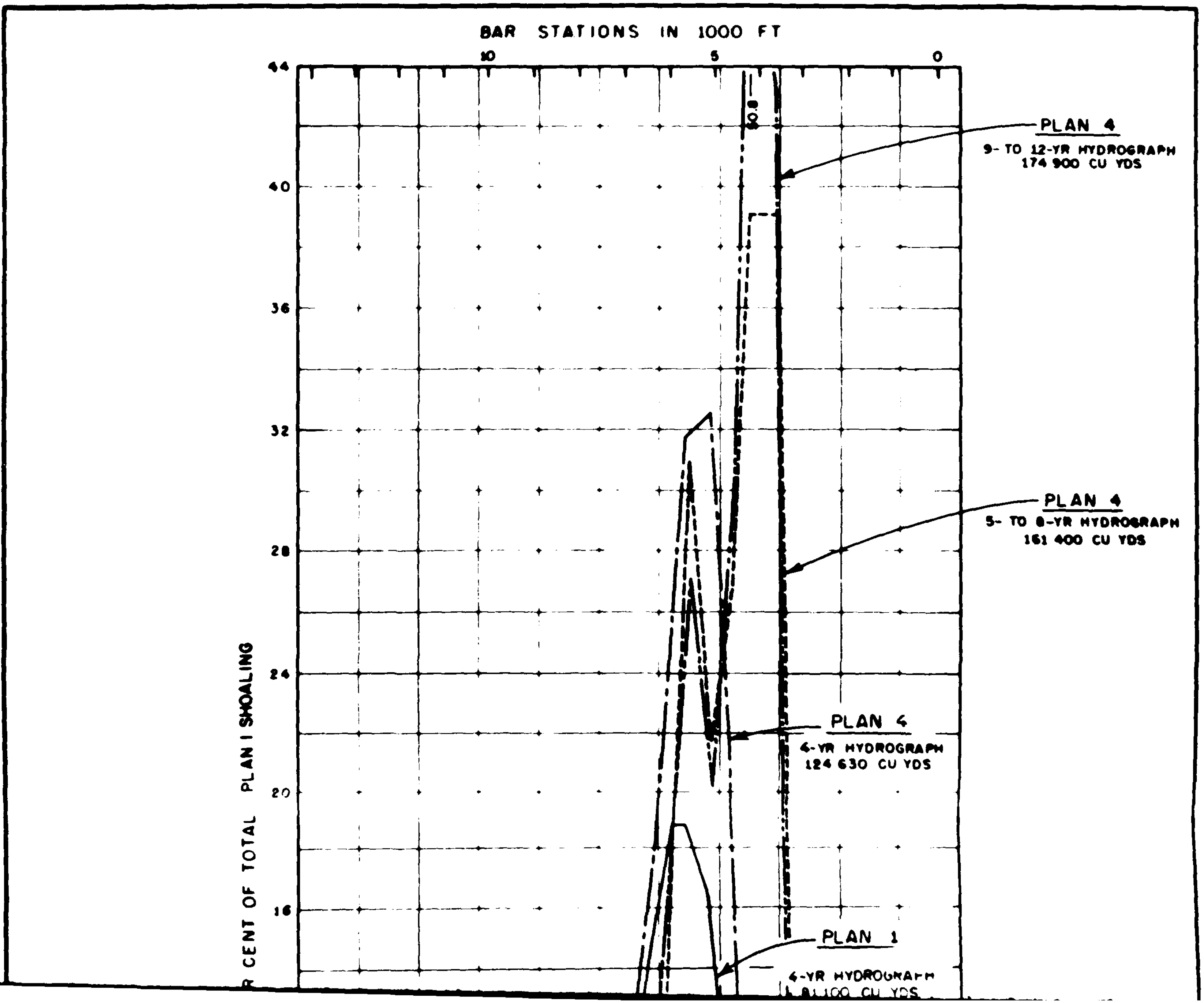
SHOALING DISTRIBUTION
STELLA-FISHER BARS
PLANS 1 AND 4

40-FT CHANNEL

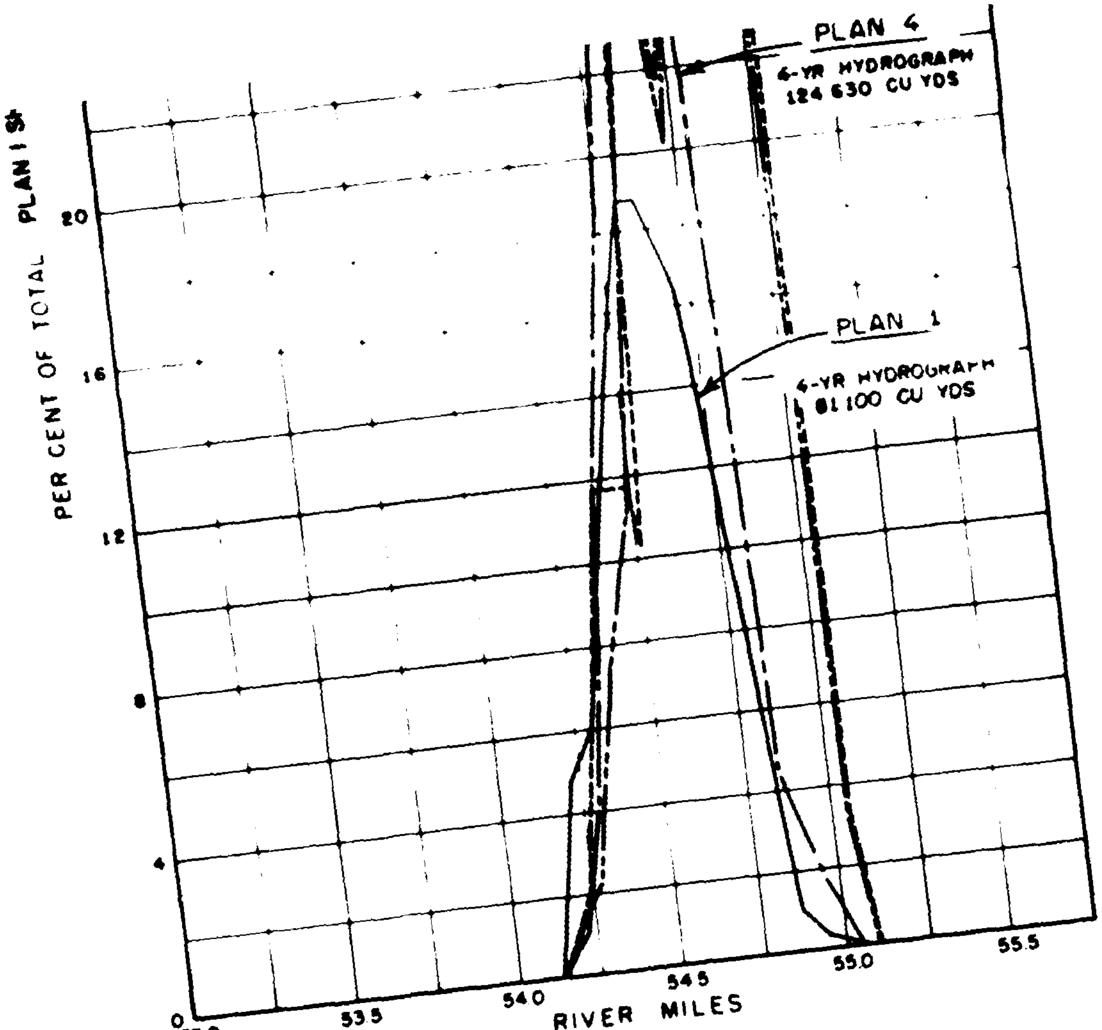
NOTES

NAVIGATION CHANNEL WAS DREDGED TO 45-FT DEPTH PRIOR TO 5TH AND 9TH HYDROGRAPHS.

QUANTITIES ARE SHOALING IN THE NAVIGATION CHANNEL ABOVE ELEVATION -45 CRD (40 FT PLUS 5-FT OVERDEPTH).



BAR STATIONS IN 1000 FT
10
5
0
44
40
36
32
28
24
20
16
R CENT OF TOTAL PLAN I SHOALING
PLAN 4
9- TO 12-YR HYDROGRAPH
174 900 CU YDS
PLAN 4
5- TO 8-YR HYDROGRAPH
161 400 CU YDS
PLAN 4
4-YR HYDROGRAPH
124 630 CU YDS
PLAN 1
4-YR HYDROGRAPH



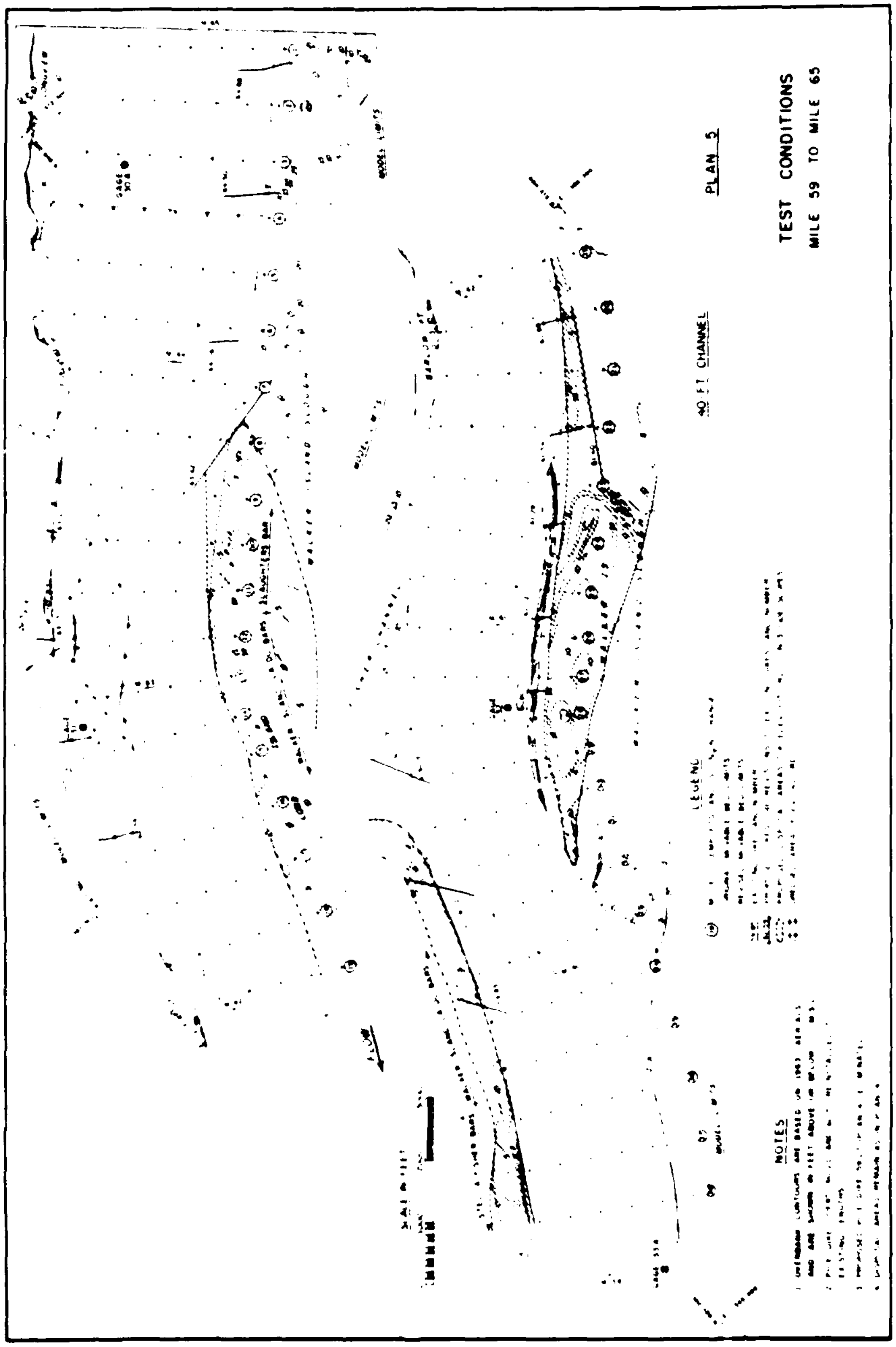
40-FT CHANNEL

SHOALING DISTRIBUTION
GULL ISLAND BAR
PLANS 1 AND 4

NOTES

NAVIGATION CHANNEL WAS DREDGED TO 46-FT DEPTH PRIOR TO 5TH AND 9TH HYDROGRAPHS.

QUANTITIES ARE SHOALING IN THE NAVIGATION CHANNEL ABOVE ELEVATION -45 CRD (40 FT PLUS 5-FT OVERDEPTH).



PLAN 5
TEST CONDITIONS
MILE 59 TO MILE 65
40 FT CHANNEL
LEGEND
NOTES
FLOW
SCALE IN FEET

PLATE 60

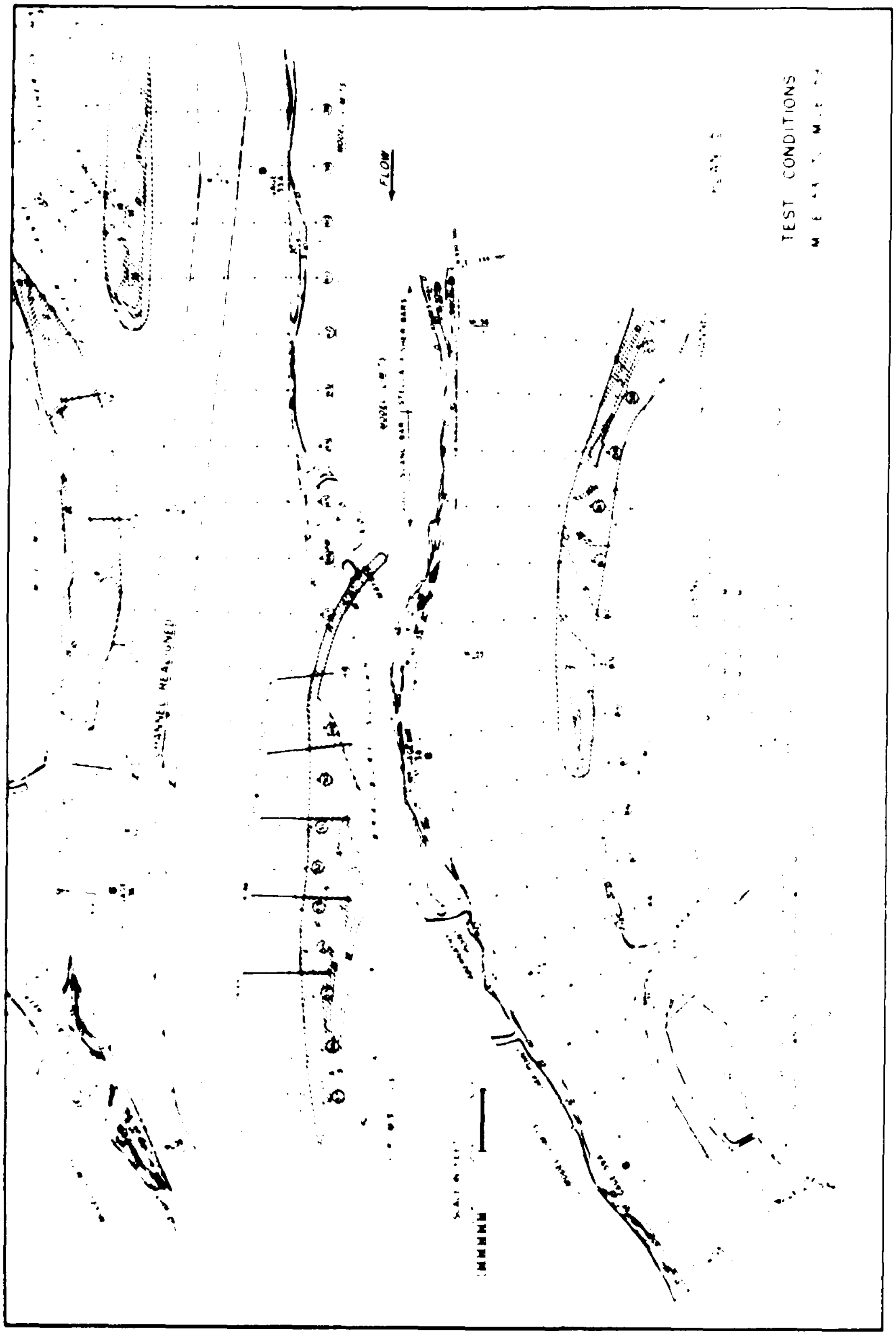
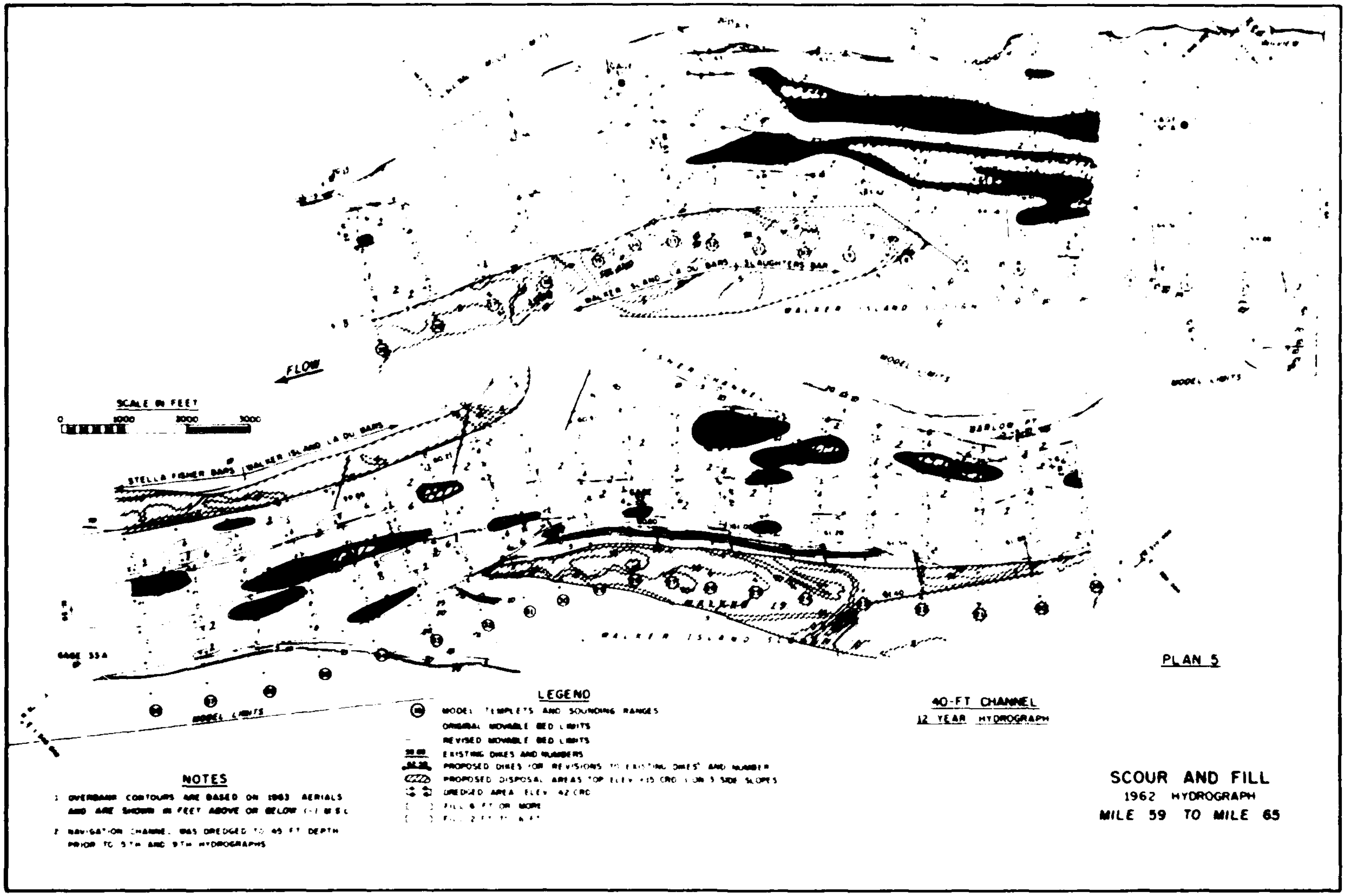


PLATE 61



FLOW
SCALE IN FEET
0 1000 2000 3000
STELLA FISHER BARS
WALKER ISLAND LA DU BARS
WALKER ISLAND LA DU BARS SLAUGHTERS BAR
BARLOW PT
MODEL LIMITS
PLAN 5
LEGEND
MODEL TEMPLETS AND SOUNDING RANGES
ORIGINAL MOVABLE BED LIMITS
REVISED MOVABLE BED LIMITS
EXISTING DIKES AND NUMBERS
PROPOSED DIKES (OR REVISIONS TO EXISTING DIKES) AND NUMBER
PROPOSED DISPOSAL AREAS TOP ELEV +15 CRD 1 ON 3 SIDE SLOPES
DREDGED AREA ELEV -42 CRD
40-FT CHANNEL
12 YEAR HYDROGRAPH
NOTES
1. OVERBANK CONTOURS ARE BASED ON 1963 AERIALS AND ARE SHOWN IN FEET ABOVE OR BELOW (-) M.S.L.
2. NAVIGATION CHANNEL WAS DREDGED TO 45 FT DEPTH PRIOR TO 5TH AND 9TH HYDROGRAPHS
SCOUR AND FILL
1962 HYDROGRAPH
MILE 59 TO MILE 65

PLATE 62

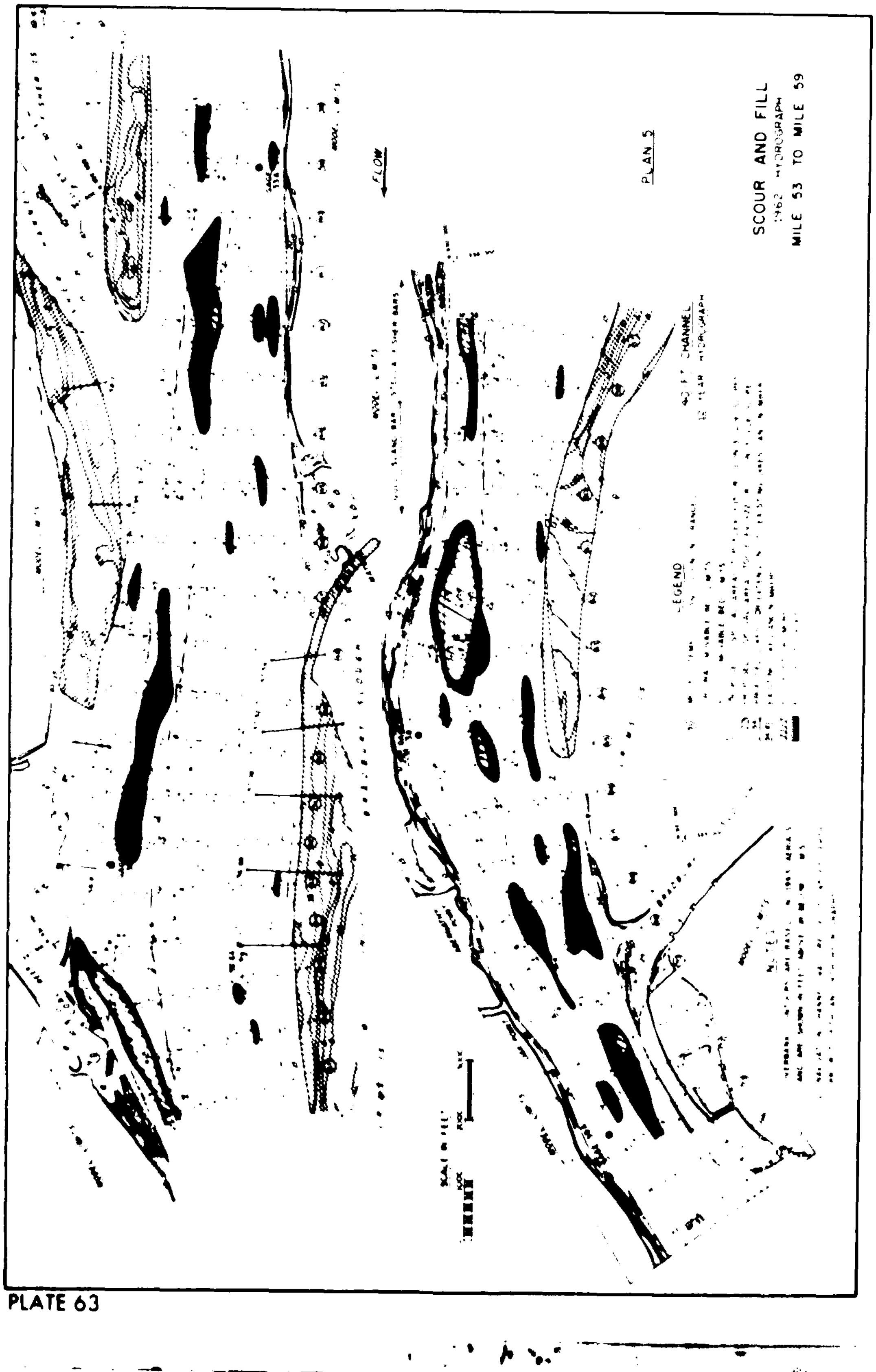
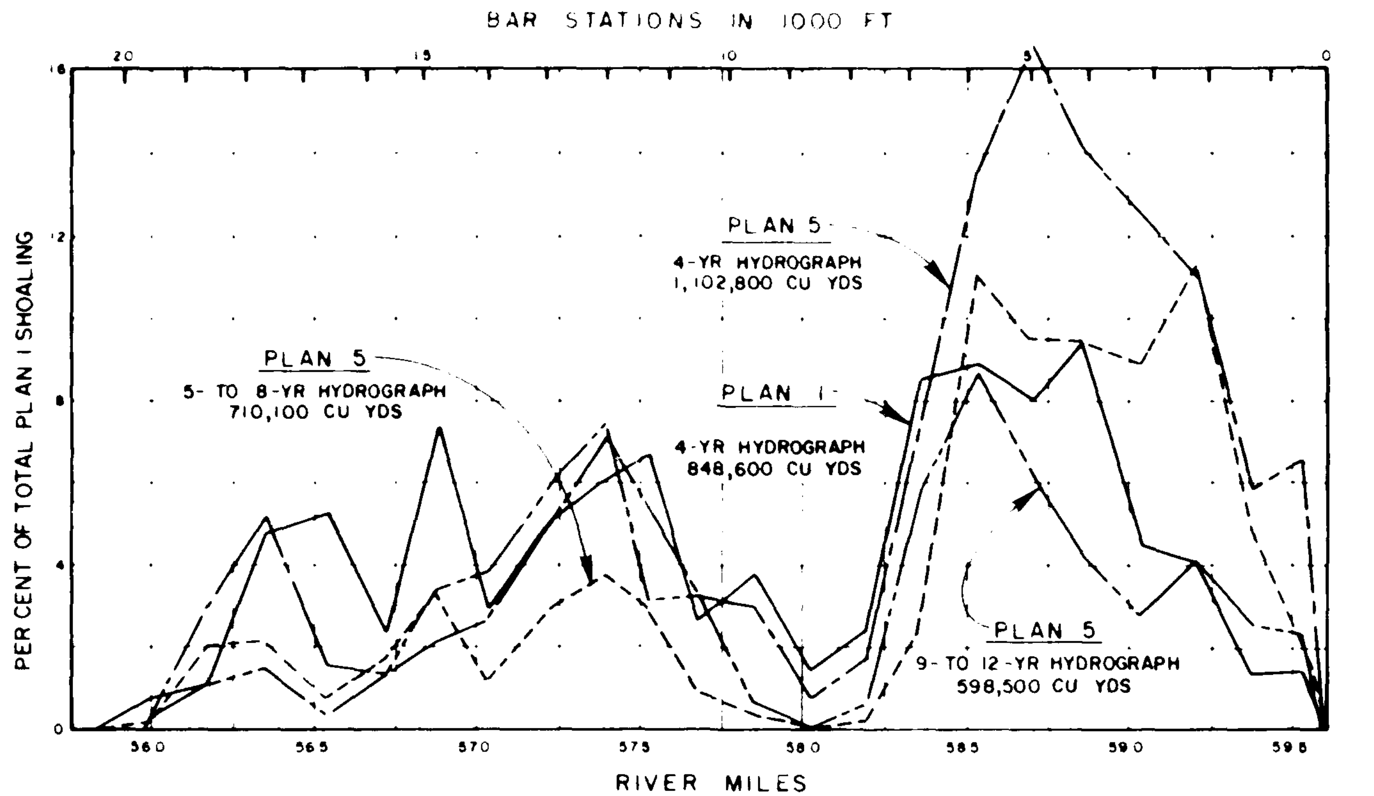

SCOUR AND FILL
1962 HYDROGRAPH
MILE 53 TO MILE 59
PLAN 5
FLOW
40 FT CHANNEL
15 YEAR HYDROGRAPH
LEGEND
NOTES
SCALE IN FEET

PLATE 63



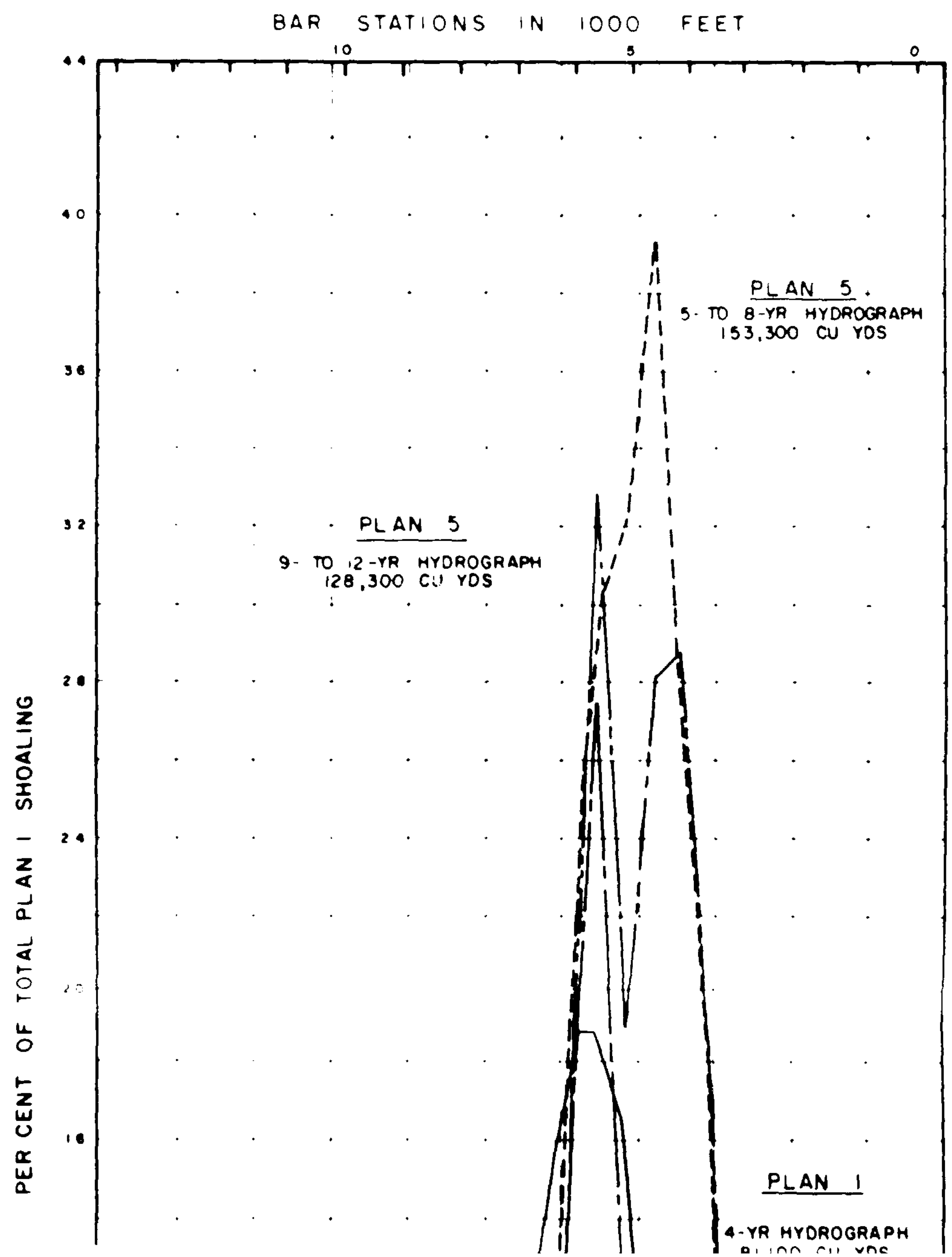
NOTES

NAVIGATION CHANNEL WAS DREDGED TO 45-FT DEPTH PRIOR TO 5TH AND 9TH HYDROGRAPHS

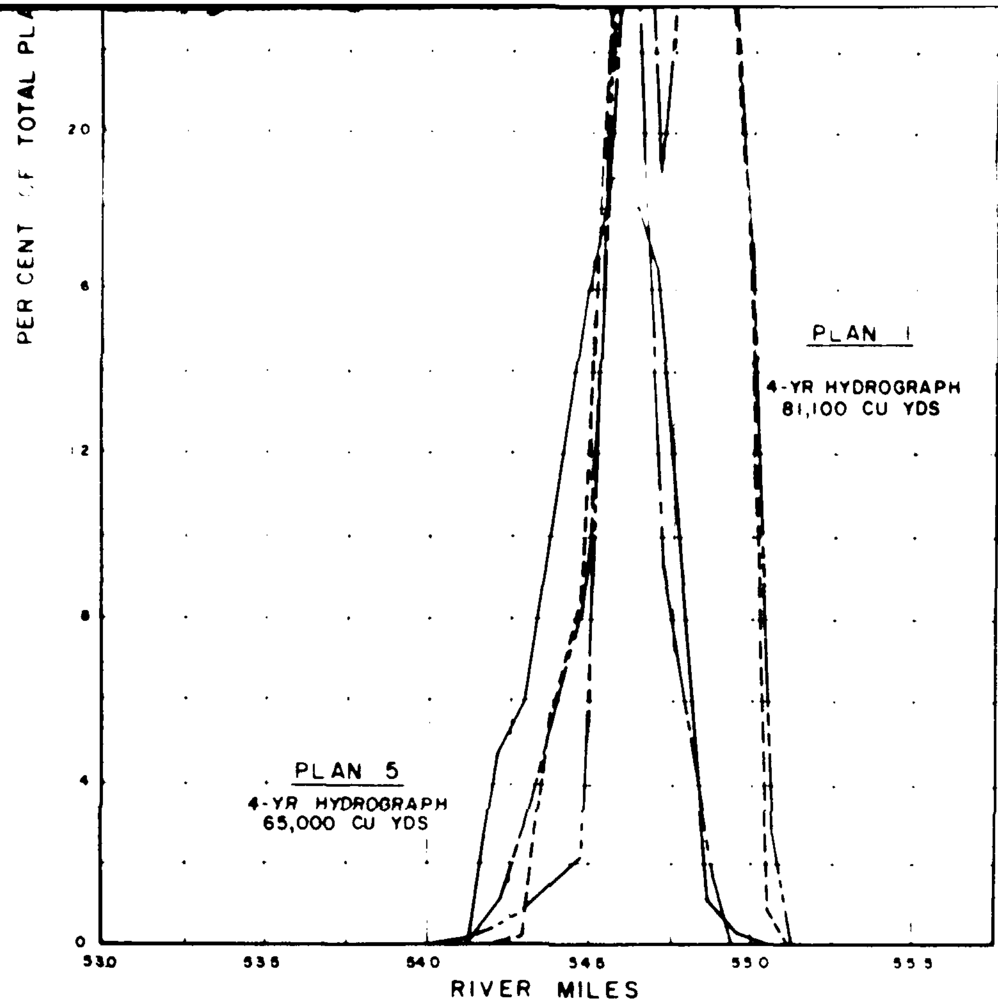
QUANTITIES ARE SHOALING IN THE NAVIGATION CHANNEL ABOVE ELEVATION -45 CRD (40 FT PLUS 5-FT OVERDEPTH)

40-FT CHANNEL

SHOALING DISTRIBUTION
STELLA-FISHER BARS
PLANS 1 AND 5



BAR STATIONS IN 1000 FEET
10
5
0
44
40
36
32
28
24
16
PER CENT OF TOTAL PLAN 1 SHOALING
PLAN 5
5- TO 8-YR HYDROGRAPH
153,300 CU YDS
PLAN 5
9- TO 12-YR HYDROGRAPH
128,300 CU YDS
PLAN 1
4-YR HYDROGRAPH



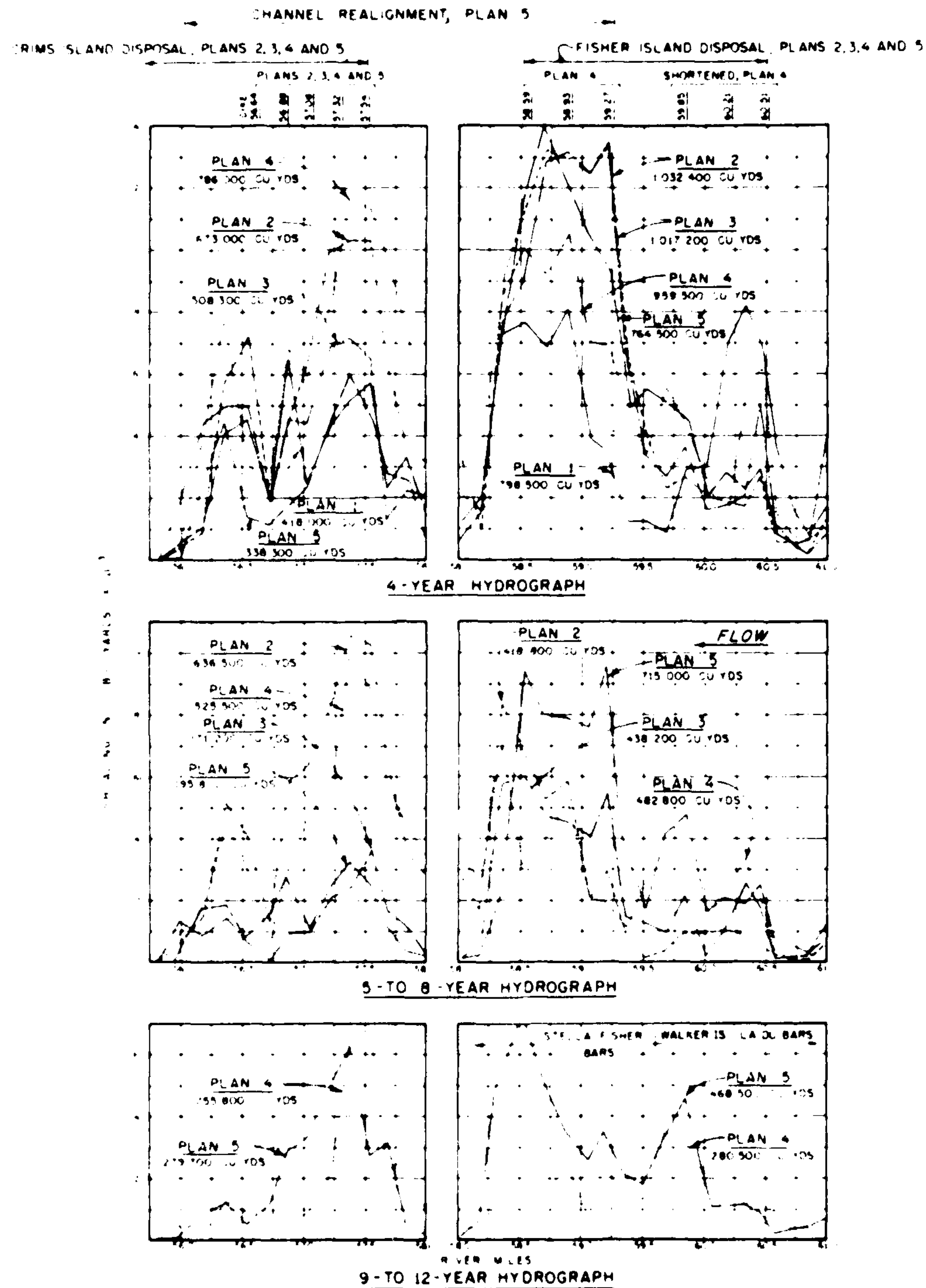
40-FT CHANNEL

NOTES

NAVIGATION CHANNEL WAS DREDGED TO 46-FT DEPTH PRIOR TO 5TH AND 9TH HYDROGRAPHS.

QUANTITIES ARE SHOALING IN THE NAVIGATION CHANNEL ABOVE ELEVATION -45 CRD (40-FT PLUS 5-FT OVERDEPTH).

SHOALING DISTRIBUTION
GULL ISLAND BAR
PLANS 1 AND 5



NOTES

SHOALING IN NAVIGATION CHANNEL
MILES 56 TO 61
PLANS 1 TO 5

DATE
ILMED
-8